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13. ABSTRACT *(Maximum 200 words)*

This project has two goals. First, is to design and build an advanced microscope, called PCM (PC Microscope), for use in both military and civilian hospitals for anatomic pathology. Second, is to rapidly prototype, using "off-the-shelf" components, two functional units that, although not as innovative as PCM, could be placed immediately on field trial in hospitals at Luke Air Force Base and Mayo Clinic communicating over the ISDN network. These units were almost completed during the first year and will be field tested in year two. Preliminary design of the hardware and software of the advanced microscope was initiated. This design process included familiarization with the working environment in both military and civilian departments of pathology; successful experimentation with the chip proposed for the PCM digital video camera to determine that it can operate at design rates that permit 30 frame per second operation in monochrome and approximately seven frames per second in color (using color sequencing); testing of the Apple Computer PowerPC-chip-based PowerMac 9500/120 by conversion from 68xxx code into PowerPC code to provide concrete illustrations of the capabilities of the 9500/120 in data manipulation.

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PI - Signature 10/30/95 Date

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1. INTRODUCTION

This is the first Annual Report for grant DAMD17-94-J-4500 received by our corporation (Kensal Corp.) from the U.S. Army Medical Research Acquisition Agency (Fort Detrick, Maryland). This work is sponsored by the U.S. Advanced Research Projects Agency (Arlington, Virginia) under the Advanced Bioengineering Program. It relates to research and development in the field of medical microscopy, especially for applications in anatomic pathology.

Typically, the anatomic pathologist views, through the microscope, human tissue extracted from about 2,000 patients per year. Ordinarily, this tissue is first fixed in formalin and then, in order to stiffen it before cutting, is embedded in parafin. Slices of tissues are generated by slicing the parafin "block" by means of a microtome to a thickness of about 5 micrometers. Each slice is placed on a microscope slide and stained with a combination of hematoxylin and eosin, biochemical dyes that stain DNA and RNA, respectively. A thin (150 micrometers) coverslip is then affixed in order to protect the tissue sample both from mechanical damage and from oxidation. Thus protected, the stained tissue will last for many years.

Approximately two or three microscope slides are prepared per patient according to the number of pieces of tissue that have been extracted from the patient's body. Each tissue sample is imbedded in a separate parafin block and a slice from each is mounted. (Occasionally, multiple tissue sections may be imbedded in the same block.)

1.1 Report Goals

The purpose of the research described in this report is to (1) become familiar with the working environment in departments of pathology both in the military and civilian sectors in order to plan a field trial of a radically new approach to microscopy for both military and civilian anatomic pathology, (2) prepare a preliminary design of the hardware of this advanced microscope shown in Figure 4 (page 10) of the original proposal, (3) prepare a Software Specification for such a microscope, and at the specific request of ARPA, (4) build in a "rapid prototyping" exercise, using "off-the-shelf" components, two complete microscopes for deployment in an initial field trial before the new microscope becomes available. The goal of the first year was to work on (1) through (4) in parallel.

1.2 Report Summary

This report is in nine sections including this section (Introduction). The Narrative (Section 2) that describes visits to pathologists at both civilian and military hospitals, Hospital Information Systems (Section 4), and Pathology Images and Information Systems (Section 5) all relate to (1) above. The section entitled NeoLensman (Section 6) and Forty Megahertz TC217 Camera (Section 8) both relate to (2) above. Section 7 (Software for PowerMac) treats (3) above and Section 3 (Rapid Prototyping) treats (4) above. The research and development reported in all of these sections (except for Section 3, Rapid Prototyping) has all been done in conjunction with grant 2 R44 GM44420-02A2 from the National Institute of General Medical Science of the National Institutes of Health. This institute has provided funding for an advanced microscope (without rapid prototyping) for the civilian sector. Of course, research and development done under the grant being reported here is directed primarily towards the military sector.

1.2.1 Sections 2, 4, and 5

Research described in these sections (Narrative, Hospital Information Systems, and Pathology Images and Information Systems) was done by Lane Garrett, Jeremy Chambers, and Laurie DeLuca of the Kensal staff. Section 2 is a narrative history of meetings that took place between Kensal staff and pathologists in Arizona. These pathologists were located at hospitals at Luke Air Force Base, Davis Monthan Air Force Base, Mayo Clinic, Veterans Administration, and the University of Arizona. The

goal here was to observe anatomic pathologists in action and to discuss with them the proposed features of the Kensal PCM (PC Microsocpe) which is the acronym given to our advanced microscope. Thus Section 2 consists of a series of trip and visit reports as organized by Mr. Garrett.

1.2.2 Sections 6 and 8

These sections (NeoLensman and Forty Megahertz TC217 Camera) relate to hardware investigations of the TC217-CCD (Charge Couple Device) "chip" that will be used in the advanced microscope. The work was done by Kensal Staff (Shane Chambers and Charles Schoonover) and by an outside consultant (Greg Kline of Kline Research). The TC217 (designed at Texas Instruments, Dallas, and manufactured in Japan) is a remarkable device that permits both dual field and single frame operation according to biases applied by external control circuitry. Kensal is fortunate enough to have in its possession three proprietary cameras that use this device. Thus Section 6 provides a user manual for the Kensal camera. The Annual Report for 1995-1996 will include imagery that specifically relates to this project.

Kline Research, knowing, probably, more about the TC217 chip than the manufacturer, itself, alleged that it would be possible to achieve an operating speed far beyond its advertised specifications. This fact was due that Texas Instruments provides no hardware "drivers" specific to this chip. Therefore, Kline Research was directed to investigate the possibility of building such drivers and operating this chip at 40MHz. The experiment was successful which implies that the PCM camera can operate at design rates that will permit 30 frame per second operation in monochrome and approximately seven frames per second in color (using color sequencing).

1.2.3 Section 7

This section (Software for PowerMac) is an introduction to our work with the Apple Computer PowerPC-chip-based line of processors that have been selected to host PCM. Two PowerMacs (model 9500/120) were purchased. One will be located in San Diego at Ken Crocker Consulting for the purpose of investigating (1) drive circuitry for the microscope stage that moves the microscope slide and (2) interfacing the Kline Research video electronics to the host computer. The other is located at Kensal for use in preliminary telemedicine experiments generating imagery using the TC217 in a "still camera" mode of operation.

Since this host computer is new to Kensal as it uses the PowerPC chip, we requested a consultant (Greg Guerin), who is a PowerPC expert, to begin investigating this computer by running test cases that required conversion from 68xxx code into PowerPC code, using the language C++ as an intermediary. These tests provided us with concrete illustrations of the capabilities of the 9500/120 in data manipulation. Section 7 reports results.

1.2.4 Section 3

This section (Rapid Prototyping) describes the function of the workstation produced under a subgrant to Boeckeler Instruments, Inc. Under this subgrant Boeckeler designed a prototype that could be rapidly constructed using off-the-shelf components. The Nikon Microphot microscope was selected and, in cooperation with the Lockheed Corporation of Sunnyvale, CA, a Lockheed ICON (Image Communications and Operations Node) was procured as the host computer. The Lockheed ICON was modified extensively by replacing its "motherboard," based on the Intel 486, with a dual Pentium computer. In addition a "frame-grabber" was added by purchasing the Matrox Magic card that could receive images from the video camera (a CCIR 601 Sony) attached to the microscope. An ISDN card was also added to permit worldwide communications over the ISDN network. Although two prototypes were scheduled for delivery at the end of the first year, this delivery has now been extended into the first quarter of the second year due to technical difficulties that Boeckeler has had with Matrox and other vendors.

2. NARRATIVE

This section is a chronological file of trips by Kensal staff to interview pathologists and collect information on telepathology and pathology procedure.

2.1 Dr. Joan Hardaway, Davis Monthan AFB Pathology Dept., Tucson, AZ

A 3:30PM meeting on 6/1/95 was held with Dr. Hardaway, with Laurie DeLuca, Victor Carless, Charlie Schoonover, Shane Chambers and the writer in attendance. Dr. Hardaway was a gracious host answering our questions, demonstrating her microscope and showing the lab with its equipment utilized in the preparation of tissue samples, until after 5:00 PM.

Dr. Hardaway does not use any pathology software at this time. But she states that "Copath" is to be made available in the not too distant future. She would like to have access to a database on her computer. Incidentally she just got a PC on her desk and is beginning to learn how to use it with the help of her secretary. Her small work area is void of any additional space. She would like to be able to append data to her data forms, call up the pertinent labs for information when needed, and pull old diagnoses again. Her group is now putting new diagnoses in the secretaries computer thus eliminating recopying by hand. The most savings could be accomplished in the secretaries area since much time is spent in expediting. The hospital uses a wide mix of computers all of which are PC clones-there is no standardization.

2.1.1 Report Generation

In the current pathology system at Davis Monthan, Dr. Hardaway dictates a gross diagnosis of a slide into a micro-cassette, and passes the tape on to the secretary to type up in a report form. Occasionally the pathologists are given the history of the case, but not always, Dr. Hardaway later receives the forms with the gross dictation on it and uses it for referral when she does her microscope examination. When a diagnosis is made, it is typed onto the report form, and in addition, must be repeated onto a card which is stored separately. The reports are stored on the Pathology Department's own Database, and she was not sure if it was tied into the HIS. When asked about the possibility of using voice recognition, she said that it would be more effort than dictating into a cassette.

2.1.2 Peer Review/Referrals

At present it is easy to Fed-X slides for peer review. An on-line connection would save a little time, but the time involved in sending out referrals is not a significant part of the process. She said that more time was spent in doing recuts and packaging. One of the problems in using a courier was that two doctors could not converse about the referral. There is also the problem of a slide occasionally getting lost. Referrals are usually sent to the AFIP. The entire block of tissue is sent to them, which they do not return. Therefore, it is necessary to make any recuts the original pathologists might need before sending the block to the AFIP. Occasionally Davis Monthan uses the Fitzsimmons A-center for their referrals, who do not insist on having the entire block. The number of referrals sent out depends on how many pathologists work together. If a pathologist works alone, a lot of referrals are sent out, even if he/she is certain of the diagnosis. This is done for documentation, risk, and liability purposes. If a number of pathologists work together, they may consult with each other in place of sending out for referrals. About 10% of her cases are sent out to another specialist for liability purposes, of these, most are skin tissue.

If an image is of the type that could go on line and get 24 hour response, "It alone could help a lot". If it could be done real time it would be "great". However she stated that we need to improve the Digital Microscope. Most of her work is done at 4x and 40x and occasionally at 100x with slide-oil-objective for special cases such as bone marrow (less than 5% of the time). The

repeatability of slides (exact same spot being under the objective) is very good. Even with 100x and oil, repeatability is satisfactory, assuming the same microscope settings. The size of slides is very uniform from unit to unit, but she did not have any specifications as to tolerances.

2.1.3 Digital Advantages

Digital capabilities would be great to mark a spot or Area Of Interest (AOI). In some cases such as individual cells a Cytotech checks for all cells, and makes a circle around each bad cell. The Pathologist then looks in the circles for diagnosis. ." According to Dr. Hardaway, cytology requires lots of searching time. She suggested that a digital microscope would help by finding pre-marked regions of interest. There is now some equipment using Neural Nets that picks out enlarged Nuclei and marks AOIs. This is a case where the computer is better, this is too tedious and a human can miss some areas.

2.1.4 Case Load

Cases of a given type seem to come in cycles, She ran about 128 Gynecology slides in the first 5 months this year with up to 5 slides per case. Non-Gynecological slides such as urine samples were about 75 in the same period with about 2 slides per case. She also does Biopsy slides which are cyclical, especially for possible skin cancer. A typical day's work consists of 1 to 3 trays of 18 slides each.

2.1.5 Processing a Glass Slide

On an average day, Dr. Hardaway receives a cassette of gross tissue that has been assigned a number and entered into a log book by a technician. She views the tissue (in the cassette) and describes what she sees. She then takes her own sample of the tissue to be placed on a glass slide. The process of taking a sample involves putting the cassette (that has the tissue in paraffin) into a heated processor overnight. This allows the technicians to properly embed the tissue sample. Next the tissue is cut into thin "ribbons" and floated on a water bath. A glass slide is immersed in the water. placed under the tissue, and lifted out so that the tissue adheres to the glass slide. The slide is then "cooked" to set the tissue in place, stained, and has a cover-slip placed upon it. when the process is finished, Dr. Hardaway receives a tray of slides, all of the same tissue contained in the cassette. She explained that for some cases, she must have several (three or more) layers of the same tissue to observe, to be sure of her findings. If she were given one or two layers, certain details might not be present that are key to the diagnosis.

2.1.6 Record Keeping

About one years written history is kept locally, (on 4" x 6" cards). Slides are stored in a local slide library. Bar codes are OK for samples in the lab, for tubes of blood, etc. but not for slides.

Getting reports to clinicians is the biggest bottleneck in the system. There is at least a 24 hour turnaround time. She does proof-reading of the transcripts dictated on tape to her secretary. The dictation machine and transcriber can sometimes present problems. They can now sign once on 4-ply paper forms - which saves some time. Dr. Hardaway stated that, ideally it would be helpful to be able to pull up information from another report, but finding a full report is unlikely. Accessing on-line records would replace the running around to fetch files by hand, and would save the redundancy of typing up the diagnosis onto a separate card. It would eliminate the "inefficiency" delays that occur. The pathology module takes up most of the secretaries time, but not the pathologist's time. Dr. Hardaway's major constraint is the budget.

2.1.7 Additional documentation

Dr. Hardaway gave us a Tissue Examination report form and a flyer on the Computer Trust Corporation's SURGE™ Single-User Core Module: inexpensive software for the smaller Anatomic Pathology Laboratory. the core module is $3K with 8 additional modules at $1K or $2K each for a total package of $14K and a $2.5K yearly maintenance thereafter. The package does not even run under "Windows".

2.1.8 Conclusion

As far as improving time and physical motions, Dr. Hardaway said that nothing could beat the microscope. Also, "The microscope image cannot be beat." According to Dr. Hardaway, pathologists are very comfortable with the current microscope technology, and she insists that a digital microscope would not replace an optical microscope. She does, however, like the idea of a digital microscope for assisted diagnosis. A Pathology workstation with digital features could be a useful tool to assist in the process. It would be used in special cases for indexing the slide, marking and returning to AOIs and possibly for data and image storage and retrieval. Sometimes slides are lost.

2.2 Boeckeler Instruments, Inc., Tucson, AZ

A 2:00P meeting on 6/22/95 (scheduled last week) was held with Steve Lange, and Bill Berchard of Boeckeler, with Victor Carless, Jeremy Chambers, Shane Chambers, Laurie DeLuca, Charles Schoonover and the writer from Kensal Corp. The purpose of the meeting was multifold, to answer Boeckeler's request for an update on what the Kensal PCM team were doing, Introduce new team members and their areas of responsibility, facilitate interaction and cross-fertilization, observe the microscopes and dual Pentium microprocessors, and ascertain Boeckeler's progress in both the software and hardware areas.

2.2.1 Hardware

Both Nikon microscopes are in house at Boeckeler, but the second unit is not compatible with the dual Pentium PC. Although ordered and shipped at the same time, the second one has different electronics in the base. They are in the process of getting this resolved with Nikon. The main problem is still the integration of the Kodak chip and the Matrox board. The Kodak chip has been upgraded to 8Mhz clock rate with a new EPROM and crystal, which should have solved the problem. The chip output looks OK on the oscilloscope, however it still is not working with the 3 megabyte Matrox frame grabber board! Boeckeler is still having communication and documentation problems with Matrox. They finally got the ISDN tariff approved, but do not have a firm install date. The ISDN link is pretty well handled by the NT operating system.

2.2.2 Software

The Software effort is mostly complete with The Front End and major Objects coded. About 2,000 lines of original code have been written with the total probably over 25,000 lines considering overhead and library items. A couple pieces of code will have to be written for the interfacing of the ISDN to Windows NT (a minor effort). Also the drivers for the microscope stage are not completed. They will interface with a new stage driver board which powers DC servos with encoder feedback. Bill offered to give our team a 3 hour briefing (evening preferably) on his software specifications, flowcharts, objects etc. I will try to set up a meeting in a couple of weeks.

2.2.3 General Miscellaneous Information

Boeckeler now has about 75 distributors (primarily microscope distributors in the Electronics and Industrial markets) with about 15 to 20 of them international. LEAD Technologies, Inc.; 900 Baxter ST; Charlotte, NC 287204; (704) 332 5532; FAX (704) 372 8161 has done a good job on their software toolbox for GUI and Image processing for Windows. Their 4096 X 2116 X 24 bits depth guide image takes about 26 Megabytes of storage. The Matrox frame grabber handles 1024 X 768 pixels. We found out from Steve Lange that the Department of Pathology, U of A have found that the Roche system looks worse at a resolution of 3200 pixels than 1000 pixels. Their current work is primarily done at 1000 pixels. The Microscopes have a Sony 3-color high resolution camera (768 X484) with on top controls for the adjustment of all key parameters. We all agreed that real-time focus was a great feature. The Sony images looked very good, giving a good impression for an instrument cost of about $6K. The Matrox board came with a bundled Pixel Viewer (Frame Buffer Viewer) that appears quite useful. Latest information indicates that they will be able to scan in rearrange and complete a full guide image in about 20 seconds. Additional server software will be required in the future if we wish to include a third active station.

2.2.4 Conclusion

Hardware, software, and ISDN hopefully will all come together for the start of peer to peer testing by the end of August. This looks like an overall slippage of six week to me.

2.3 Dr. James Byers,VA Medical Center, Tucson AZ 85723

On June 28th Jeremy Chambers, Shane Chambers, Laurie DeLuca, Charles Schoonover, and the writer visited with Dr. James Byers at the VA Medical Center in Tucson. Objectives were to learn about his procedures, methodology, and computer and Hospital Information System interface if any. Another major objective was to discuss telepathology to the extent that he was familiar with advantages and disadvantages of the current technology.

Dr. Byers was interested in our activities and was even familiar with Arvie's Work at Boeckeler (he is a neighbor of Arvie's). A gracious host and good educator, he gave us almost two hours of his time. Our group of five from Kensal was directed by Dr. Byers to small room adjacent to a clerical pathology office. Dr. Byers manned the main microscope which had four other Binocular stations for other viewers. Two cylindrical extensions in opposite directions from the main microscope carried the light approximately 2 feet from the source to the small-footprint observer stations. The observer mounts could each swivel approximately 90 degrees about the normal to the desk-top plane and were positioned opposite to each other. Dr. Byers could point to regions of interest within his field of view with a super-imposed transparent arrow. All other viewers could also see this arrow. The main microscope had several levels of magnification and illumination. A Sony 3 CCD RGB camera was mounted above the main microscope. The camera's real-time output was directed to a high-resolution RGB monitor and a Polaroid digital film recorder for color hard copy output.

2.3.1 Case Analysis

Dr. Byers explained that pathologists may see several types of specimens per day. We discussed types of cases that did not require structural analysis such as blood cell examination. One type of specimen he referred to was called a peripheral blood smear (usually from the Hematology Dept.). This is a relatively simple procedure, commonly performed in doctor's offices, in which a needle is placed into a peripheral vein to draw out some blood. When pathologists receive a peripheral blood smear, There are basically three types of blood cells, red cells (about 7 microns in diameter) which are often used as a reference for relative cell size, and

two basic types of white cells. Particular attention is given while viewing the slide, looking for any inconsistencies.

A second type of specimen a pathologist might receive, is a cytology study. These are typically Pap Smears in which the pathologist is looking for cancer. Smears, such as Pap smears do not have any tissue structure. Often Cytotechs will be used to examine the whole area of the slide and mark any suspicious ROI's, thus saving time for the Pathologist.

In similar cases Radiologists may suspect a lesion (such as found in the Lung) and request a biopsy. This frequently will be an aspiration which is almost non-invasive but usually results with enough material for a satisfactory diagnosis. With a Fluoroscope the Doctor can accurately observe the position of the needle and get a sample from the area of interest. A Valley Fever case was used to illustrate the point. The pathologist will then view the slide to determine if a biopsy is necessary. If it is not necessary, the physician and patient can avoid an invasive procedure all together. The role of the pathologist here and in other procedures is to make available as much information as possible to both the clinical physician and the patient. More information can be determined from tissue than from any other procedure.

In many of these "non-structure" cases only one or two slides are necessary. (Dr. Byers at this point let us view a Cytology Slide of a Pap Smear. He explained that he was looking for clusters of cells, of which there were not many.) The examination of a case can take a few minutes, especially if a Pathologist is confirming a prior diagnosis or up to an hour on a difficult case where he may also go back for more samples.

For cases where whole tissue is sampled, structure is important. When Dr. Byers looks at a slide under the microscope, he looks for the pattern of growth, the array of cells, and the architecture when trying to make a diagnosis. He does not just look at one cell or one cluster of cells. Dr. Byers often cycled the microscopic focal plane through most of the tissue regions he was examining under high magnification. This appeared to give him further structural information about the specimen i.e. the thickness and location of object-boundaries in his regions of interest. He usually looks for two or three other cells or features to confirm what he is thinking. It is crucial that Pathologists be accurate in their diagnoses. The difficult cases make up less than 5% of the total cases.

Cancer cells often have more than two chromosomes and appear more mitosis than normal cells. This is why they usually show darker than normal cells (the stain preferentially shows chromosome material). In unusual cases special stains may be ordered to show special immunological effects. Use of antibodies which react with cytoplasm is being utilized more frequently. A difficult case may involve an area where the pathologist has not had much experience, or a rare type where referral to expert(s) is required. Referrals are usually to AFIP, however a pathologist is free to go to another preferred source for a particular case.

In discussing briefly the role of Cytotechs, Dr. Byers said that they were limited in how many slides they could view in one day. The limitation was placed on them since fatigue can set in and result in sloppy work. When the Cytotechs at the V.A. Hospital find an abnormal cell, they mark a blue dot in the 9 o'clock position adjacent to the cell so that the doctors know where to look. Other cytotechs at other institutions have the equipment to place a ring around the bad cell. Quality control could probably be enhanced in some cases where "rectilinear or rigid" scanning swaths over the specimen are used during the initial analysis. Rectilinear/rigid scanning refers to using strictly orthogonal stage motion where either the x or the y (but not both) motion control is used independently. Thus, the specimen is viewed at a fixed magnification starting from the left end (and proceeds to the right end) of the slide and is completely studied by moving through a snake-like path of overlapped linear scanning swaths. This is a very tedious process and is usually performed by a technician. The cytotech takes a rectilinear look at a case, scanning the whole slide.

For tissue where structure is important, a Pathologist may take multiple cuts and also look at the structure in "3D". Each slice cut with a microtome ranges in thickness, about 3 to 5 micron per sample. If the slicing is too thick, pathologists can't see all of the morphology to make a proper diagnosis. Dr. Byers explained that there is no universal convention for slicing tissue, that it depends on the institution where a pathologist works. The slicing procedure is important though (which direction it is sliced in, etc.), and this is why they perform a gross examination prior to the slicing. A gross exam reveals such thing as the mobility and color of the tissue to the pathologist. This type of information will determine how the slicing is to be done. An example would be Renal (Kidney) tissue.

Biopsies of skin lesions are sent in by regular doctors who give a description of the case along with patient history for diagnosis by the Pathologist. Tissue samples of this type or those from tumor biopsies usually require extensive structural examination. Here a high resolution guide image would be required. (As a point of reference 80% to 90% of the better images available on-line are satisfactory for diagnosis.) For the more difficult cases a "Differentiated" Diagnosis is performed with possibilities arranged in decreasing order of probability. Additional tests are performed, samples taken, peer review requested etc., with exclusion or confirmation until the extra options are eliminated. Some cases are just "tweeners" where the case seems to fall between two categories. Where structure is important, several slides per case are the norm with difficult cases often taking more.

2.3.2 Telepathology Comments and Observations.

Dr. Byers is not hooked up to a telepathology system, however his demonstration/conferencing area with the five-station binocular microscope gives some of the same features and is used primarily for training. This is almost like an internal telepathology setup. The main microscope is equipped with a Sony real time camera hooked up to a Trinitron monitor. There is a video link to an upstairs operating room that is not normally used.

Dr. Byers focused on demonstrating pathological methodology and analysis of stained slide specimens from several case studies. There is no standardized method that pathologists use to measure the accuracy or quality of their diagnosis over time.

KSC asked if having knowledge of the percentage of total tissue viewed could be used as a gauge for quality control. Rather than answer directly, Dr. Byers demonstrated several scenarios where such knowledge could be useful and where it may not be useful.

Dr. Byers said that older pathologists are much more skeptical about telepathology than younger pathologists. (His mind-set is with the younger pathologists) The younger doctors are growing up with computers, etc. and are therefore more prone to use telepathology. Before Dr. Byers transferred over to the V.A. Hospital, he went to China with other pathologists from UMC to work on a telepathology system. They used telephone lines for transferring images, and typically transferred a case (5-7 images) at one time. It took anywhere from 30 seconds to 5 minutes to transfer each image at 14,400 bps depending on the phone lines, etc.. One problem that he encountered with the images was the low resolution. A second problem that he predicts, is that real-time consultation and data transfer will not be reasonable to use in the real world of Pathology. He explained that the expert on the other end of the system is not going to want to sit around and wait all day for a Pathologist or clinician to transfer images at his convenience. He said that appointed times are a must. Images and comments can be transferred ahead of time without problems. Dr. Byers does feel that telepathology can be used, though, if properly applied.

Dr. Byers feels that low power magnification for guide images is still somewhat of a problem in that resolution is still to limited, however the best available over the Web are usually

acceptable. He foresees a Quality Pathology Workstation, where text, arrows, verbal comments could be added to high resolution images for transmission to an expert center such as Memorial Sloan-Kettering Cancer Center. For example when 5 cases and their images are up-loaded, the experts could be called for consultation. Perhaps sessions could be scheduled every 10:00 AM to 10:30 AM on Monday, Wednesday, and Friday. On-line real time consultation is probably not good unless it is with a very remote site with no pathologist, maybe with a cytotech or regular physician. Some areas of diagnosis will be more of a problem such as skin lesions where 80% to 90% are hard to determine and Lymphomas are always a problem. The UoA seems to be having some success with images regularly coming in from Kingman, AZ and Mexico for example.

2.3.3 General and Miscellaneous Information

Dr. Byers explained that pathology has been very descriptive for the past 150 years (definitive categorization of diseases). Descriptive criteria often includes how much blue there is from the stain (the more blue, the more DNA), how big the nuclei are, and the amount of mitosis going on (which determines the rate of growth). Pathologists have been adding to the database of "Histopathologies"? since 1860. Pathologists get as much information as they can and will now even give a Prognosis in cancer cases where a person has a probability of living for a given length of time. Pathology is currently moving toward more focus on the genomic structures of cells (DNA make-up, etc.). In addition, more usage of antibodies which react with cytoplasm is being promoted.

A Cytotech will have a BA and at least one year of training while a Pathologists requires 10 years of training to become an expert in a specific area. Cytology studies the patterns and numbers of cells in a sample. "Pink" and "Blue" are the colors resulting from the standard stains. Experienced pathologists normally do not use atlases for their areas of expertise, but may look up information on unusual cases or cases in areas outside of their normal area(s). In a timed mock run of using an atlas for reference, Dr. Byers found what he was looking for in approximately two minutes. He stated that they may use an atlas for referencing about once a month. A specific "look-up" may only take a couple of minutes, however the atlas had generally poor photographs. (**Diagnostic Surgical Pathology**, 2 volumes, Editor: Stephen S. Sternberg, Raven Press, ISBN: 0-88167-442-7). Many pictures were black and white, a few were color but all were of relatively poor resolution.

QA processes are coming to play in the Pathologists' world. Photometrics are being developed and peer review is being encouraged. This is currently low key at the VA hospital, however cancer cases are always reviewed by two pathologists "independently".

The CAP is now accrediting Laboratories. More frequently pathology labs are seeking accreditation with CAP or other state agencies to improve their image and help standardize their operations (which we assume makes referrals easier). CAP accreditation requires that certain methodologies (not described) be adopted and reports (not described) be made regularly through hospital management. Dr. Byers said that at first the standardization of operations was welcomed by pathologists but that there has been some resentment toward CAP for over-policing (no further explanation was given) their work. The paperwork and additional checks and balances add costs but do add to the status or prestige of the hospital. Administration does keep track of the work load which justifies staff and expenses. Naturally many reports are generated for the VA. KSC asked Byers about his interaction with top management in the hospital. He said that reports describing work load and throughput (i.e., patients, slides, paraffin blocks, etc.) were compiled monthly on paper and given to management. Byers did not know any information about the VA hospital's HIS or whether his secretaries had access through their terminals in the adjacent office. Our impression is that Dr. Byers likes to keep his distance from the HIS world. He seems to leave this up to the secretaries.

Dr. Byers is connected to internet and the Web at 14.4Kbps through PrimeNet, a local service provider. The hospital is planning to have direct access in September. He shared with Laurie his list of the best Web sites for good pathological images that he had previously compiled. He observed that the JPEG images are of better quality than the GIF images. Laser Discs usually do not have acceptable images. He plans to use the images primarily for teaching.

One of his associates (who was not in at the time) is their "Local Hacker Pathologist (forgive the pun)", **Ron B. Schifman**, (MD, Staff Pathologist). Ron is hooked up to the local Windows net, has a Sony monitor (estimated 640 by 480 resolution), a 1 gigabyte hard drive, a five CD ROM drive with random search, and a color printer for recording images. Ron is planning to get a better resolution color printer to improve his output. There is also a RGB camera and microscope hooked up to their local net. He has made "Medline" CD-ROMs accessible to all networked staff. "Scientific American Medicine" CD-ROM is planned next. Bibliographic retrieval is a hot item for the new medical staff.

2.3.4 Suggestions for a Pathology Work Station

Some features to include would be specialized information helpful in the diagnoses of Hepatitis Types A, B, or C. It would be nice to pull up the patient enzyme test results along with any available expert data base information. At first look, a Pathologist may not refer to the Physicians data and patient history thus giving an unbiased view, since the clinician often states what he thinks the disease is. Having this data on-line could be useful for later reference. In reports, SNOMED is often used along with some Pathological abbreviations such as BCC for Basal Cell Carcinoma. Alphanumerics are used to help cut time on about 90% of his cases. Having some reference books on line such as Sternbergs and Robbins? could also be useful.

2.3.5 Conclusion

Dr. Byers personally has archived 16,000 Kodachrome slides of his work. Perhaps a digital archiving system could come close to the costs of film and provide more convenience and quicker access. With improvement the PC Microscope and Telemedicine will be useful in a variety of cases. "Better" guide images, on-line references, annotation capabilities, and quick archival ability, would add to the PCM utility.

Dr. Byers was most helpful, an excellent host and educator with a real interest in using the latest technology wherever applicable.

2.4 Review "Windows" Software for Boeckeler "Off-the-Shelf" PCM

On Wednesday the 12th of July we have scheduled a visit with Bill Berchard of Boeckeler Instruments and Jay Nance at KSI (the Executive Conference Room). The purpose of the meeting is to discuss and review Boeckeler's "Windows" software as used on their "off-the-shelf" PC Microscope design.

We will meet at approximately 6:00 PM in the large Executive Conference room. Due to the hour, and Jay coming down directly from a course in Mesa, Pizza and soft drinks will be served. Bill has a broad software background with IBM and a lot of experience with "C/C++" on the PC platform. His approach, documentation methods, and software specifications for the dual "Pentium" workstation will be educational and most helpful toward our efforts. We will soon be starting the PC Microscope projects where we are striving for multiplatform capability. Jay is currently completing Kensal's "C/C++" software standards and will be helping us with our software specification and coding efforts on the PC Microscope. The meeting is expected to last until 9:00 to 9:30 PM.

2.5 A.K. Bhattacharyya, MD, UofA, College of Medicine, Tucson, AZ

A 9:55 AM meeting on 7/19/95 was held with Dr. Bhattacharyya, Laurie DeLuca, Victor Carless, Jeremy Chambers, Shane Chambers, and the writer in attendance. After briefly previewing the planed meeting, Dr. Bhattacharyya led the discussion and demonstrations until 11:15 AM. He was very responsive and open to our questions and only begged ignorance on some of the technically oriented queries. Data gained from the conversations are enumerated in the following paragraphs but not necessarily in sequence. Dr. Weinstein and Dr. Martinez were unable to attend. We will try to meet with DR Martinez at a later time for some of the more technical system questions.

Dr. Bhattacharyya explained that the pathology group at UMC specializes in OBGYN, liver, lung, kidney, and hemopathology cases. All Doctors have their subspecialitie(s). The cases get reviewed by three pathologists to ensure the quality of the diagnosis. It was not clear as to whether all of these organ systems are being reviewed on a regular basis with the Roche telepathology system. Only the "questionable" cases are being referred to them and about two thirds of these can be diagnosed satisfactorily with the system. Of the remaining cases additional information, tissue samples, or other regions of interest are requested and about half (one sixth of the total) require the glass slides. The doctor doing the diagnosis is dependent on the remote Dr. for selecting and sending the proper images, this is not perceived to be a problem. Case information is transmitted with each set of images. A report goes back to the referring institution. About 400 telepathology cases have been done to date. The system is useful in Triage cases. Dr. Bhattacharyya spends an average of 7 hours per week (10% of his time) in telepathology. The telepathology system with improvements can be useful for Morphometrics, Cytology, Consultation Services live teleconferencing and in the future providing and archiving size and dimensions of ROI's. For Quality Control purposes they are getting 4 to 5 consultants to review each of their cases.

The Roche system used NEC Multisync 17" monitors with an apparent .28 dot pitch and an estimated refresh rate of 60 Hz due to the noticeable flicker. The Roche telepathology computer system was based on a 80486 with 32 MB Ram, a 24-bit graphics card (NDI TIGA True Color?), MS Windows OS, a high-speed modem (unknown bps), and some telecommunication and graphics software (called ImageManager). We saw two of these systems that were installed at UMC, similar systems were installed at each referring institute.

The telecommunications software is constantly left in the "auto answer" mode so that it may receive images without human supervision. They are using the new version (2.2) of the Roche software. An Olympus Camera was mounted on top of the microscope in their upstairs computer laboratory which was in turn connected to another Roche computer. Images received by the system seemed to be a constant 1024x774 pixels in size (24 bits-per-pixel). Image transmission for this size image took 2.3 minutes per image, actually 7 minutes for three images. Image quality and contrast varied with the Doctor who set up the sending system and his experience level. The best images come from Dr. DeLeon in Mexico. He is the chief of pathology in Hermosillo, Mexico. The paint-to-screen of the 1024x774 image from its decompressed archive was slow (about one or two seconds) on top of the slow decompression time (about three seconds). It took about one minute and 20 seconds to find and pull up old images from the archives. For demonstration 6 images were retrieved. Total load time can take up to 20 seconds. Other image sizes apparently are not used since the monitor can not resolve them. Remote sites can scan-in images of 1536/1160, 2044/1450, and 3072/2320

Dr. Bhattacharyya called Dr. Fleishman in Cottonwood, Arizona at 10:05 am but was unable to get him. He then called Dr. Nelson in Kingman and asked him to send several "colorful" images to us for demonstration purposes. There was a delay of about 15 minutes before the

transmission started. Two plain push button phones were available near the Roche computer for such calls. Dr. Bhattacharyya said that he preferred a hands-free conferencing/speakerphone for collaborative specimen discussions with remote groups. Dr. Bhattacharyya struggled to dial Dr. Fleishman and Dr. Nelson--he looked around backwards to the computer screen for the number and then turned to the phone to type a few numbers and repeated this action. An auto dialer built into the software with telephone conferencing ability could greatly simplify these manual operations. Dr. Bhattacharyya had difficulties in navigating the software. Any software we write must be as intuitive as possible, and any non-trivial operations should be hidden away so only a technician can get at them.

Dr. Nelson's case was a needle biopsy of a tumor that immediately looked like Breast or Prostate tissue. No information was initially given to prevent any bias. Three images were received 4x, 10x, 40x. All three images were looked at simultaneously on the screen. A diagnosis of High grade Prostate Cancer was completed in 3 minutes. (Dr. Nelson also had a 60x lens available on his microscope.)

DR Bhattacharyya could overlay red (or other color) arrows and outlines of any orientation along with text on top of an image. Further, outlines could be made by point- click-drag operations. Text can also be annotated to the image. There is also the possibility to call up a history file that can be transmitted with the image. The overlay could later be removed to reveal the underlying imagery. A case from Mexico was shown with an excellent image of a Subcutaneous Lesion. There is also the ability to scale images, scroll them up and down and tile multiple images on the screen. Thumbnail images are used to give a quick look, on screen size is estimated at 128x128 pixels. The software package has a generally good looking GUI with pull down menus, buttons for action selection, and scroll bars where applicable. The intuitiveness and logical progression of the system could be significantly improved. Dr. Bhattacharyya had not used the system for two weeks and had to rediscover where to find some items and get the desired information. Dr. Bhattacharyya wished there were *morphometric* related tools in the software so that he could compute area, length, etc. of the outlines or other markings. He said that Roche is "looking into" adding such features to the software.

Maximum storage in the system is 500 images. The images are then archived by Dr. Martinez, a University of Arizona Electrical Engineer. All image file names appeared to be based on the date they were received and were placed into a single directory. All image information is manually logged into a blue ring binder for later reference. A relational database like "FoxPro" for archiving and retrieval would be most useful.

Dr. Bhattacharyya repeatedly had to reload the imaging software because of mistaking the "File:exit" command with other functions. Reloading the software took roughly 50 seconds. Dr. Bhattacharyya allowed Shane Chambers to work with the operating system on both of the Roche computers to determine the system makeup. Dr. Battachara, proclaiming his computer illiteracy, marveled at Shane's ability and suggested that he be hired to operate the Telepathology system instead.

The original cost for the hardware was $25,000; $3000.00 for the microscope, $7000.00 for the camera and $15,000.00 for the computer, etc. Additionally the software cost $15,000. UMC thus paid a total of $40,000 for the system. Specifically how much was spent on the two Roche 486 computers is unknown. Three software updates have been received since the system has been in operation. The system in Dr. Weinstein's has had a camera change from a German to a Sony camera. An Olympus microscope is used. The focus feature (maximize a contrast number on the screen) was demonstrated. The ocular and screen focus were different, requiring final adjustment by the system optimization routine. A few of attempts were made with an excellent image finally obtained. Focus is adjusted in real time on a thumbnail view of about 128 x 128

pixels estimated. Time to adjust and capture a good image is about two minutes (not counting relearning the system).

Dr. Bhattacharyya recommended that we speak to Dr. Martinez (621-6174, Secretary: 621-2718), who was unavailable during our visit, for technical questions and a discussion of UMC's HIS.

Within Arizona, five hospitals belong to the triage telemedicine network (UMC is the hub for these hospitals). U of A also networks with Dr. Zimmerman in Mesa and Dr. Alverez in Yuma. They have had a few trial runs with a hospital in Sedona. Dr. Bhattacharyya commented that thus far the network has been limited to just state-wide hospitals since legal issues for inter-state networking have not yet been fully resolved. Some progress has recently been made in Congress however. Test cases have been run "unofficially" with a hospital in Colorado that would like to be in the network when possible. Approximately 20 phone numbers are listed in his "phonebook". International connectivity has been established between China and Mexico with good results. To date, 400 telemedicine cases have been handled by Dr. Battachara and the group. We thanked Dr. Bhattacharyya for the more than two hours of time given to our group.

2.5.1 Conclusion

Telepathology regardless of complaints and objections, is frequently a useful tool that with, changes in legislation, improved hardware, better user-friendly software, and education to create more familiarity among pathologists, can be a productivity tool which also enhances the quality of diagnosis through team effort. Being able to call-up old images cases etc. by a relational data search would be most useful. The Roche system does not have an archiving feature. Frequently Dr. Bhattacharyya will set up a 35mm camera on a tripod in front of the screen to capture images for his records. This costs $8.00 an image instead of an "$800.00" charge to send out and have images transferred to film. Archiving is even more important in training hospitals where certain illustrative images need to be handled by multiple individuals. Dr. Bhattacharyya briefly mentioned the possibility of image enhancement and quantitative DNA analysis for special cases e.g. (Pap smears). Roche indicated that they are "looking" into this area. This could be a subject for our future study.

2.6 Scottsdale Memorial Hospital

AM and PM meetings were held with M. Pattie Madjidi regarding HIS, and Dr. Peter Jolma regarding pathology respectively. Scottsdale Memorial is a progressive hospital and willing to try the latest developments. They evaluated the latest HMO HIS integrated system with an advanced GUI and turned it down due to its very slow operating speed. The old DOS system was significantly faster. The main computer storage database is housed at Scottsdale Memorial on Osborne Road (SMO), while most of the pathology work is done at Scottsdale Memorial North (SMN) off Shea Boulevard. SMN works closely with the pathologists at Mayo Clinic. There will be less interaction when Mayo builds their own hospital north of Bell Road near Scottsdale Road.

2.6.1 CoPath

Pattie Madjidi, MT has broad pathology knowledge and administers the CoPath system at Scottsdale Memorial. She was most helpful and kindly responded to all our questions. The CoPath installation and its linkages with other systems at SMN and SMO was the center of our discussion.

CoPath is a complete stand alone system. It was chosen by Scottsdale Memorial North because it is the "Cadillac of pathology systems, and very easy to use," Ms. Madjidi said.

HBO&C's system was much harder to work with; it had a very poor user interface and used a lot of screening.

The way the CoPath system works is that everything must be linked through Word Perfect 5.1. This limits viewing capabilities into other areas, such as lab reports, because since CoPath is not Windows based, the system must be exited before entering into another one. When Ms. Madjidi performed a demonstration of this, the transition took about 20-30 seconds. Her one improvement to the system would be to integrate into the pathology system so that there would be an easier way of viewing other areas without exiting the CoPath system. She said that it would be nice to have a patient demographic link to the HIS.

When asked if the physicians used the computers, Ms. Madjidi said that they use charts instead of computers for recording the history of patients because it was much quicker for them.

CoPath was installed at SMO in 1991; since then, no old records stored in the CoPath system have had to go off line into storage--plenty of space within the system is still available.

Pattie explained that it was hospital policy to purchase only HP PC's. CoPath was installed on these HP PC's. However, CoPath exclusively deals with Dell PC's, thus the $11,000+/yr. CoPath service contract with SMN did not cover PC hardware problems and was limited to maintaining a bilateral interface between a 486-based file server (with an oddly 14MB of RAM) for CoPath and three "ARNet Panels", apparently some kind of interface hub for all the networked PC's and printers using CoPath. Collaborative Medical Systems (CoMed) is responsible for repairing the software of the system. When a repair is needed, it is done over a modem. Scottsdale Memorial is a Hewlett-Packard user, which is non standardized equipment for CoMed. This is why they are only responsible for software repair. In addition, CoMed is only responsible for getting information from the file server to the RNet ports. Three RNet panels are used as the ports in the system. From there, the hospital uses in-house hardware for the rest of the connections. All of this equipment resides at the Osborne location of Scottsdale Memorial. It has a real-time link with the other hospital. CoPath maintenance is always performed through a modem interface and is done remotely. SMN employs a technical crew on site to maintain the PC hardware, among other unspecified duties. CoPath at SMN was linked to SMO via a T1 line. The CoPath file server is located at SMO.

Installed on the HP's along with CoPath were: WordPerfect 5.1 (word-processor, not the latest version available: 6.0), Software-Carousel (an old, out of production, DOS application that allows several applications to reside in memory simultaneously, with hot-key inter-application switching), and a terminal emulator. Neither CoPath, nor these other applications were Windows-based; rather all four were DOS-based. CoPath Windows-based workstations are available but Dr. Madjidi said there has been no effort put forth yet to acquire these.

Pattie Madjidi operated through the CoPath user interface in a very fluid manner, and appeared to know well all the features available in the CoPath system. CoPath appears to have both developed a very natural user interface for Pathologists and provided the appropriate end-user training.

When asked what the weak points of the CoPath system were, Ms. Madjidi stated that there really were none for her. She likes the system and said that it runs great. She did show a preference for a Windows environment, however. In addition, she tends to like the idea of a touch screen, although no one else has shown an interest in that. She stated that CoPath is the "Cadillac of Pathology Systems" as opposed to HBO's pathology module, which was more "cumbersome" to use. Recall, CoPath went live in 1991 at SMO/SMN and that all records entered since then are on-line. We attempted to clock the time required to call up records since 1991 through 1995, however, retrieval was almost instantaneous for records as old as 1991. Recall that the file-server

for CoPath was located remotely at SMO, some 16 miles away, available through a T1 link. The CoPath system is MUMPS based.

The term *accessioning* refers to assigning a number to a specimen case. A patient may have more than one case, and if that is so, their date of birth or name regulates all of them together. Accessioning numbers are regulated by having a prefix of some sort (for example, "N" for the north hospital) at the beginning, the year it was produced next (i.e. 95), and then the case number (the sequence of how the cases come in). There are then an unlimited number of parts that can go under each case. For example, a slide may be labeled with Part A, which refers to the liver. A second slide may be labeled with Part B, which refers to the lung. Finally, there is a block listed under the part or subparts. The blocks refer to the different areas taken from a chunk of the tissue from the paraffin block. The number of blocks varies depending on how many areas the pathologist wants to view. The CoPath system prints labels like this for the slides produced at the hospital. The information must first be entered into the system, and is usually done so by a surgical pathology assistant instead of the pathologist. It should be noted that multiple slides are made per block, based on how many different types of stains are to be done, and how many slides the pathologists wants from that particular block.

Accessioning, or the assigning of alpha-numeric codes to pathology cases, is furnished automatically through CoPath and is based on a coding-system designed by Scottsdale Memorial. Accession labels are printed in batch and attached to all bags of paraffin bounded specimen blocks and the resulting slide-specimens. A typical accession number is as follows:

N95-1411

The "N" is an origination indicator which stands for Scottsdale Memorial "North" Hospital. The "95" is the origination date (1995). The 1411 is the case number.

The alpha-numeric hierarchy in the accessioning process is illustrated (extrapolated from Pattie's description) as follows:

```
N95-1411 : SMN 1995 case #1411
      |
      +-->N95-1411 A : Liver
  |
  +-->N95-1411 B : Pancreas
              |
              +-->N95-1411 B1 : Pancreas, block 1
              |
              +-->N95-1411 B2 : Pancreas, block 2
                           |
                           +-->N95-1441 B2 1 : Pancreas, block 2, slide 1
                           |
                           +-->N95-1441 B2 2 : Pancreas, block 2, slide 2
```

Once specimens have been mounted on glass, prepared slide labels contain:

Cassette # / Accession #
Block #
Mayo Clinic #
Date

"Surgical Pathology Assistants" prepare the slide labels, instructed by the dictating surgical pathologist.

If a referral is done on a slide, the turn around time in usually one day. When a referral is sent out, the "send-out" portion of the system keeps track of it. In addition, it prints out a letter to go with the slide, and has the capability to mark "return" if the slide is to be returned. The number of slides lost or broken is less than one percent, Ms. Madjidi said.

The Histology module, for any given case, could show how many and what kind of tissue specimens were logged into the system, what stains were ordered for those specimens, could print cover reports for referral slides, and could print "outstanding slides" reports for missing/referred slides.

CoPath can perform searches on the following fields: specimen number, medical record number, patient name, attending physician, and time frame.

CoPath handles CPT (Current Procedure Terminology) codes which are necessary for billing. The billing interface to the HBO Clinstar billing module was via manually transported diskette rather than a direct interface. CoPath also automatically assigns SNOMED codes (topographically based) by reading[1] the logged diagnosis. Dr. Madjidi explained that SNOMED codes are required by their "Tumor Registry" located at SMO. The registry compiles statistics which are forwarded to national registries. Pattie did not elaborate on the kinds of statistics generated or for what purpose.

When conducting a search in the system, specimen number, attending physician, medical record number, or patient's name can be used to pull up the information you are looking for. In addition to this, SNOMED coding can be used. SNOMED codes define a specimen by diagnosis and topographical location. For example, and SNOMED code will tell you that a tissue is from the breast and that it is carcinoma. SNOMED has thousands upon thousands of codes for all of the possible information necessary. Ms. Madjidi said that this was good for tracking specimens to search for later on, and that it also keeps track of things internationally. SNOMED is intended for use by the Tumor Registry Department, which must report to government and state agencies. All hospitals have their own Tumor Registry Department which must report to a main hub. Therefore, everything is reported. Ms. Madjidi also added that SNOMED searches are very quick.

As far as billing is concerned, fee codes are entered when the specimen comes in. This is the only link to the hospital information system they have. Standardized codes are used for insurance company reasons.

Records are not archived, Ms. Madjidi said. Everything since 1991 has been kept on a database, and there is still plenty of room left. Everyday back-ups are performed also. This is done on site, but at a different location. As far as accessing records from three or four years back versus a month or two ago, there is no difference in search and retrieval time. It takes a couple of seconds at most to pull one up.

The only wish-list items that Dr. Madjidi has for CoPath is, 1) a light-pen, of which she has used before on other systems, but she is not exactly sure how it might be integrated with the CoPath user interface, and 2) a windows implementation. When asked for CoPath weak points, Dr. Madjidi could think of none.

The HBO&C system was briefly cited. It is known that at least the HBO Clinstar (a "laboratory system", said Pattie), and Trendstar are installed at SMN. From KSC in-house surveillance literature[2], the TRENDSTAR is a "decision support system that guides decision making. It offers `point and click' access to diverse sources of information, powerful analytical functions and extensive reporting and presentation tools. TRENDSTAR complements HBOC's

STAR and HealthQuest financial and clinical products by providing managed care contracting and monitoring, quality and case management, budgeting, forecasting and strategic planning solutions to support enterprise-wide decision-making."

Application Software:

- Hospital Systems Library
- Clinical Cost Accounting
- Contract Payment Advisor
- Management Cost Accounting
- Marketing Systems Library
- Resource Utilization Analyst
- EpiTREND Reporting System
- TRENDPATH

"HBO Clinstar" was not in any of our literature. If it is a "laboratory system", then likely it is the STAR Laboratory, described as, "an advanced system designed to ensure quality of outcome through far-reaching communication, data integrity and management control. Extensive quality control features help ensure the reliability of test results and the appropriateness of care delivered."

Application Software:

- Order Management
- Test Processing
- Patient Inquiry
- Patient Result Reports
- Quality Control
- Administrative/Management Reports
- Surgical Pathology
- Advanced Microbiology
- Advanced Blood Bank
- Contract Management

One last final note, Ms. Madjidi said that the hospital produces about 15,000 Pap Smears and 10,000 surgical slides annually. From September 1st through the 15th, she was able to pull up on the computer that 769 surgical slides had been produced.

2.6.2 Pathology

After quickly reminding Dr. Jolma, Medical Director of Scottsdale Memorial, of the nature of our visit, he kindly agreed to spend 30 minutes with us due to his busy work schedule (however, due to his interest later, we stayed a full hour). Our focus was to present our vision of the ideal telepathology system and allow Dr. Jolma to critique it. Further, we gained insight into his work and asked him to explain to us what kind of automation could improve his work. He was helpful in answering our questions and gave us some good ideas to keep in mind.

When asked what areas of technology he would like to see improved, Dr. Jolma stated that it would be nice to be able to pull up prior images from a past biopsy on the screen to compare it to a current slide in the office under the microscope. He said that this would be especially helpful with bone marrow and leukemia. If a patient was receiving chemotherapy for leukemia, he could pull up an image from the past and compare it to what he has in his office to see the progress that has been made. He also felt that the whole area of cytology could benefit from this too e.g. (with abnormal Pap smears). Other areas where history and cross-correlation of data would be helpful include; Colitis, Liver, Kidney, biopsies, and D&C's. He stated: "It would be interesting to see how D&C's respond to hormone therapy."

Dr. Jolma agreed that a market exists in rural hospitals such as one he knew in Paysen, AZ. He cautioned us not to indicate himself as a reference in case we followed up in Paysen.

Dr. Jolma next discussed what he felt would be "helpful computer aids."

The first aid would be to display image-based biopsy history of a patient on screen side-by-side. Currently he must swap several slides in and out from under the microscope, while retaining visual/heuristic knowledge of removed slides and comparing these to the current slide under microscope. An example was bone-marrow biopsies from patients undergoing chemotherapy--would like to quantify differences in specimens over time, to determine the next treatment step. Placing the imagery side by side simulatenously on a computer screen with sufficient resolution would be very helpful.

Dr. Jolma felt that the whole area of cytology could benefit from such computer-based technology. Had mentioned something about CLEA requirements but we didn't have time to determine what CLEA and its requirements are.

Dr. Jolma also stated that being able to pull up a history of slides on the screen at one time could be helpful because there tends to be observer variation among different pathologists as to what the degree of abnormality is.

Regarding voice recognition, Dr. Jolma felt that there was a place for it in the future. He had observed an old Kerswell demonstration in Boston where there was still much work to be done. What he has experienced in the past has been a struggle to use, but if advancements have been made to the point where you don't have to talk robotically and change your vocation, then he thinks voice recognition would be terrific. First of all, it would reduce some costs and reduce turn-around time with the clerical help. They are to dependent on the clerical help. This also holds up the diagnosis and the release of the patient from the hospital. Voice, he said, would speed things up and reduce the cost of secretaries. Auto-dictate to script would be great. He does not feel there would be any resistance by pathologists to use it; they are just waiting for a good system to come around. We asked him if he had any comment on the physical interface used in voice recognition systems. He indicated that a head-set or microphone was no problem at all for him to use as pathologists must get used to microphones on dictation machines and other physical interfaces such as the microscope. Thus, as long as the using a given physical interface enhances work without degrading concentration, such an interface is desired and accepted. Dr. Jolma showed preference for a voice activated system since not too much commotion goes on around them to disturb it.

Dr. Jolma said that he desires more collaboration among local pathologists for diagnostic concensus building on hard-to-diagnosis specimens. He explained that currently, each Pathologist has his own office and works there with his, "pile of glass". Often he would like to take a difficult specimen to a college and get his opinion. We pointed out that such unannounced drop-in visits with other Pathologists are probably not always at a convient time; it would be much better if the consultation could be done digitally through a local email system so that the consultant could review the digital specimen at his earliest convienience, much like voice mail and email messaging works to increase efficiency. Dr. Jolma raised no objections. Not only would this eliminate a Pathologist's footwork between several other pathologist's offices, but would also furnish rapid diagnostic turn-around since several pathologists could examine the specimen simultaneously and forward their results to Dr. Jolma's workstation. Dr. Jolma said that such technology will become increasingly attractive since, "the lawyers have discovered the Pathologist," and increasing 'patient vs. the pathologist' legal activity is, "driving this technology."

Dr. Jolma would also like to see pathologists break away from the office and work more together in a big room. This would facilitate communication as well as consulting, and

pathologists would be able to trade slides around. They would be working much closer together than alone, as they are in the present office situation.

Dr. Jolma feels that the true savings from telepathology will occur with the small, remote hospitals which may not employ a pathologist, but only a technician. Instead of a pathologist having to travel out to the hospital once a week to diagnose slides, the image could be sent to them over the telepathology lines. When queried about the desired resolution for a guide image, Dr. Jolma suggested that of a red blood cell (6 to 7 micron).

As far as using telepathology for referrals, Dr. Jolma prefers to have the slide in his hand. If an image were to be used, the sending pathologist may limit the areas to be viewed, causing a biased diagnosis. Dr. Jolma strongly felt that he would like to see the entire slide at high-magnification, and not just a small ROI section. In fact, he would hesitate to sign his name to any ROI another pathologist had subjectively produced, forwarded to him, and required his proffesional diagnosis. Somehow, the entire slide should be online for Dr. Jolma to review--either the entire slide must be digitized or be remotely available in a physical sense for real-time scanning and analysis. This necessity may suggest that Kensal seek to design a mechanical carousel/cabinent of some kind that could robotically load/unload slides, requested from remote sites, into the PC microscope. Maybe a heirarchy of robot linkable slide containers of varying sizes could be designed, with each suited for various client requirements. Alternatively, a digital container, made solely of RAID[3]-technology, with the capacity to store a score or so of slides who have been completely digitized with the LSDA and the lensed microscope for temporary on-line storage could also be produced--however this would require a tremendous amount of high-speed automated rectilinear scanning at all levels of magnification over the entire slide. Further, "stiching" software[4] would need to be developed to remove lens distortion and piece the digital pictures together into a distortion free resulting image.

With the slide in his hand, there is no selective choosing of areas to look at by the other doctor. Medical/Legal restrictions will be a driving force. If we can down-load prior images and show areas observed - this may alleviate some of the concerns of the pathologists.

Interestingly, Dr. Jolma had a multi-viewer, pipe-line-esq, microscope on his desk-top for at least three simultaneous viewers. We did not ask him how he used this--perhaps one use is for diagnostic consensus building? If so, he must coordinate schedules for one or two other pathologists to hold a group review session. The advantage to such a session is that all can express their opinion verbally, immediately, and together while seeing the same image, with a session moderator--Dr. Jolma (he controls the group's visual ROI). However, the scenario may be likened to the different collaborative results yeilded when comparing the standard "brain storming" session with a "nominal group technique"[5]--the latter yeilds greater productivity and more results in less time. The nominal group technique is analogous to our technology used in a non-real-time fashion[6], namely emailing image-based querries to the queues of other Pathologists for review and later merging the results-data at the orgin of dissemination for concensus overview. The cycle could be itterated to reach for unanamous agreement. If after several itterations, unanimity is not reached, then the specimen could be reffered to a outside specialist of that specimen's organ system.

Dr. Jolma's suggestions were that we learn more about Image Analysis, and them "marry" it to telepathology. Dr. Jolma strongly suggested that we consider including image-analysis with our workstation. "If you can marry image analysis with telepathology, I think this would very good." Dr. Jolma next spoke of image analysis of nucliea and suggested that we check MEDLINE for current papers on Medical Image Analysis. There have been some NIH studies in this area. Image analysis involves looking more at the nuclear material, such as for cancer, and has inroads in flow cytology (which does better than the human eye). Nuclear Image Analysis involves the

computer recognizing the characteristics of the nucleus and if it is Bi, Tri, or Tetra-ployed. This could be a new area of interest for Kensal, marrying telepathology and Nuclear Image Analysis.

2.6.3 Conclusion

Dr. Jolma yielded useful input in a timely and forthright manner; this input spawned some very interesting possibilities, some previously conceptualized (revisitation should cause us to think again more seriously about these possibilities). In review, some key points I feel need further discussion are as follows:

Follow up on nuclear image analysis with MEDLINE; if our technology can be meshed with nuclear image analysis, get back in touch with Dr. Jolma for more specifics.

Discuss requirements of scanning entire slide at all levels of magnification--discuss the required two phase stitcher; phase one to remove lens distortion and add color balance, etc.; phase two to convert a slide coordinate into an ROI image through stitching together several phase-one corrected capture images. NOTE: it may be better **not** to create a single large image from scanned pieces but rather to stitch pieces together "on the fly" for immediate presentation, as is evident in Preston's Infinite Roam technology and Adobe Photoshop's approach to updating large images on screen.

Discuss robotic sample containers for on-line remote selection and loading into PC microscope.

Discuss potential for an "in-house" LAN based telepathology system for diagnostic consensus building between offices of pathologists through the nominal group technique.

2.7 UMC/Cortex Medical Management Systems demo by Judith Krebs and Mark Stevens (cyto geneticist)

Mrs. Krebs was coming into Tucson to check on the newly installed Gold Standard System at University Medical Center. She agreed to meet with us and perform a demonstration so we could see how their system worked. Cortex Medical Management Systems is very interested in linking up with us so that they may include imaging into their system.

On 9/18/95 Arvie Lake, President of Boeckeler Instruments, Inc., Kendall Preston and the writers visited the University Medical Center (UMC) for a Cortex *Gold Standard* demonstration arranged by Laurie.

The system uses a Novell and Ethernet networks and gives reasonably fast response. Judith has found that doctors are definitely becoming more interested in computers. There is a trend for doctors to dial in from home, sign out reports with their electronic signature capability, etc. In addition, there system has 3 to 4 levels of security built in including a login code, a Cortex identification number, a password for pathologists who type up the reports, and then a forth level code for someone who wants to change a report.

Approximately 5 universities, 6 to 10 big clinical labs and 12 to 18 mid-size hospitals are using their system. Numerous smaller reference labs, cytology labs near hospitals are going to the *Gold Standard*. There are about 75 users of the system which handles Cytology, Anatomical, and Surgical Pathology. Most of these institutions use it for anatomical/surgical pathology purposes.

When asked about the acceptance rate of using computers, Mrs. Krebs stated that there was a greater acceptance among younger doctors than older ones. The older doctors tend to like to stick

with what they are most familiar with, which is having slides and reports in their hands. She estimated that out of their 75 installations, about 50% actually use the computer system.

The system provides several levels of security depending upon the application, For example only a pathologist can certify changes in his report. There are two major files, the Case file and the Case History file. The Case History file is on-line, (they have about 5 years of storage on a one Giga-byte hard drive with only 18 months of records). They encourage everyone to transfer information into the case history file after eighteen months. They do not archive optically yet, records are backed up on DAT tape using Colorado Mountain Software.

Cortex recommends backup; daily, weekly, monthly, and every half year. The system uses a report writer "Advanced Revelation". There are several ad hoc reports that are standard or custom reports can be easily generated. Note copies are in Lane's file. The system we viewed was their DOS system. They are in the process of switching over to a Windows system which incorporates the Windows 95 system or the 3.1 system. Mrs. Krebs said that she expects about one-third of their users to convert to the Windows system. They have two beta sites happening right now (chosen because of an interest by the beta sites), and hope to have a fully functional Windows system by Christmas. UMC is using all modules of *Gold Standard* which include Cytology, Histology, Autopsy, Billing, Support, and Query.

The system holds all prior patient history (data entered by Cortex). Records can be accessed by Name, Medical Record, Birth Date, SSN. and Admission number. They can toggle over to LIS etc. through a custom interface. The Pathology system uses status codes (1-9) to help simplify data taking: 1-case entered, 2-history printed, 3 gross entered, 4 gross printed, 5 diagnosis entered, 6 Diagnosis printed, 7 case signed but not locked down, 8 case signed and locked down, 9-billed history. The system doesn't store the slide number but only the case number. All information is on line in "gross" format but printouts use various codes. CPT (Current Procedure Terminology), custom billing codes, ICD for diagnosis, and SNOMED are all used. As far as case numbering goes, the system itself can assign a case number or a person can type one in. The system also contains SNOMED codes for tracking, but Mrs. Krebs stated that she thought SNOMED was dying out because it tends to be very time consuming to work with. There are only four basic reports, but a facility may have several versions of each. there are also Work in Progress, Case History, Regulatory Report, Statistics Reports mostly in Cytology. Most reports are one page in length, however the Autopsy report may be 5 to 15 pages in length. UMC has written its own custom 4-page cytology report. An HP LaserJet printer is used for output. "Orbit Enterprises" provides their digital signature software which works well. The new "Windows" software will allow then to more easily Fax reports.

Cortex is working on speech recognition but today it is still a problem for pathologists. Third parties are working to allow interface with images. The company has 50 years in pathology and started its first sales in 1987. The current DOS system is very stable. Pathologists can learn the system very quickly and the Transcriptionists do the rest. Searches are very fast due to their special status codes and indexed fields. They have a relational database with variable length fields. It takes about 10 seconds to call up a case. Cortex is unique in that its staff is small but very available. Training is a big part of their effort. They are not limited by size, most systems have several workstations, but an Australian installation has 50 workstations. They also have active well trained users' committees and a users' group who help decide on new features. one third of their sites were represented at a recent users conference. They are planning to be on the Internet shortly. There are a dozen competitors of which only 2 or 3 are serious. About 4 out of 10 or 12 pathologists are fully trained after the first training session while another 5 need additional help. The system employs several beneficial features. There is an extensive help list. A keyboard template shows the application of each of the function keys which can be significant time savers. The overall HIS uses a Sunquist system and has a LIS module. An "AO" module interfaces between the Sunquist system and the old Anatomical Pathology Module which is written in

Mumps. Several of Cortex's customers use the Gold Standard instead of the HIS pathology module supplied by the HIS vender. "Since Cortex specializes-they do it well".

The Cortex system has four one-way interfaces, One to IDX for billing, two to ADT for admissions, three to the HIS, four to Sunquist for billing. Cortex can also receive information from Sunquest. Visual Basic is being used for the upcoming "Windows" version. The Advanced Revelation uses R Basic and R&R Report Writer and Crystal Reporter. HL7 is used as the standard interface. Bar-coding is used for cassettes and patient information and Requisitions. Scantron is used to enter Cytology reports.

UMC runs 2000^+ pathology reports a month plus cytology reports. A typical day was counted with a total of 166 reports. There are about 10 to 30 cases per pathologist per day. The word processor can also spell check. MS Word will be used with "Windows" so new words can be added easily. The current system uses electronic billing to reduce paperwork.

2.7.1 Conclusion

Cortex seems to have made good inroads into pathology information systems and will be a company to closely watch if they can be successful with "Windows 95". Perhaps we can help them with imaging and interface to the PC Microscope Pathologists' workstation.

2.7.2 Attachments

In Lane's File Cabinet under UMC:

1. UMC Surgical Pathology Report, 3 PPS
2. UMC Cytology Report, 1 PPS

2.8 Mayo Clinic, Scottsdale, AZ

One of the three "blind" slides received from Mayo Clinic (from one of Dr. Weiland's associates) was scanned in-house and printed on the color "Fiery Cannon" at 200 dpi (11" x 17") format. The LCD scan produced 100 vertical lines per inch with a maximum of 1024 pixels per line. Three scans were conducted using red, blue, and green filters with merging and matching accomplished in "Adobe Photoshop".

Some color mis-registration was observed (cyan). This did not significantly hinder the reading of the "Guide Image" from the print. With observation the vertical scan lines (100 per inch) could easily be observed, the 200 lines per inch (horizontal lines) are observable to a nearsighted person especially without glasses.

Upon the opening of the print, Dr. Weiland did a quick scan of the guide image and observed three samples of tissue. The center sample had already been marked (blue ring of dots) by a previous observer. Within one minute, he stated that "He knows what he wants to see." In another half minute he stated: "He has everything that he wants to see for diagnosis." It then took one minute to carefully mark the print with a sharp X for each Region Of Interest and the desired magnification level.

There were seven ROI's chosen all at an additional 20x. Two of the seven sites were also requested at 40x for a total of 9 magnified images. Four of the sites were in the previously marked image, two were on a second sample of tissue while the last was on a third sample.

Dr. Weiland stated that he thinks he knows what the guide image shows, but reserves the definition until he sees the final magnified images. He had no complaints as to image quality of the print.

2.8.1 Conclusion

It appears that this approach will be satisfactory in simulating Telepathology with our present equipment. Although more time and cost is required for the prints, our general approach is verified. Having the prints as documentation is a significant advantage. When we stated that the final PC Microscope will document all portions of the guide image that the Pathologist has observed; Dr. Weiland was enthusiastic in his interest and support.

2.9 References

1. Dr. Madjidi was did not clarify how the diagnosis was understood by the computer but upon suggestion of AI, she agreed that this must be the way SNOMED codes were generated from the logged diagnosis.

2. Literature from HBO&Company, 301 Perimeter Center North, Atlanta, Georgia 30346, Phone (404) 393-6000. Descriptions from "STAR SOLUTIONS" leaflet (HBOC 8-794).

3. RAID - Redundant Array of Inexpensive Disks

4. Apple has successfully accomplished image stitching of a mosaic of pictures taken with an ordinary lensed camera in their QuickTime VR extension.

5. See my book summary, “Management Information Systems, A Managerial End-User Perspective”, KSCTR-9506, p. 7.

6. It is also analogous to the way we build consensus with our note-taking effort for greater accuracy and information content.

3. RAPID PROTOTYPING (by Steven R. Lange, Boeckeler Instruments, Inc.)

The Boeckeler TSS1 (Telemedicine Support System for Pathology) consists of workstations working together over an ISDN telephone link. The Boeckeler TSS1 can work in a single (stand alone) workstation, or in a dual mode configuration. All workstations can send and receive images. This allows one pathologist located at one part of the country to send or receive images from remote locations. All of the workstations use state-of-the-art, off the shelf components.

The workstations have the following features:

- Windows touchscreen control of X,Y,Z stage and all functions
- Non-complex screens
- Multitasking computer system
- Graphical User Interface screens and controls

Two telepathology instruments were fabricated for the purpose of conducting experiments to:

- Test the productivity of a two telepathology instruments for the purpose of conducting experiments to compare ordinary microscopy in conducting an examination.
- Test the performance of the pathologist using the instrument in its telepathology mode for conducting the same or similar examinations.

Each workstation consists of the following:

- Microscope including stand, objectives, eyepieces, illumination and condenser with provision for computer control of focus, objective power, condenser and illumination.
- Stage with motorized X, Y motion with manual/computer control.
- Full slide scanner including Kendall Preston Jr's patented "lensless microscopy" technique to obtain a "guide image".
- Personal computer with touchscreen activated graphical user interface and image capture/display, compression, dcompression, storage, retrieval, transmission and receipt capabilities for images and verbal dialog.

3.1 Function

The primary functions of workstations:

- Obtain guide image by scanning the entire microscope pathology slide and capture and display the images in high-resolution color.
- Scan user-designated "areas of interest" at user-selected high magnification from 2X to Acquire user-designated high magnification images of sample under study.
- Utilize JPEG software compression algorithms to compress/decompress images for storage and/or transmission.
- Decompress and display stored/transmitted images.
- Provide for user entry of six-digit surgical number for each image.
- Transfer images, location, coordinate data, magnification and other pertinent subject data to the second work station over ISDN high-speed telephone lines.
- Allows for simple, intuitive user control of all system functions utilizing a touchscreen control interface.
- Record the X,Y location of the stage and the magnification once per second while the system is in the single-station mode and record to a file for the purpose of analyzing the motions of the pathologist.
- Record and playback of verbal dialog attached to image files.

3.2 Operator Functions

The operator/user manually loads a pathology slide into the carrier and presses the appropriate button on the touchscreen to initiate the scanning of the slide. The user can change the position of the X, Y stage, and also fine focus the microscope image on the CCD camera with computer assistance.

The operator/user must manually turn the system on and off when required, and manually load or remove a slide from the carrier when requested. The operator will visually check and make sure the slide is loaded in the carrier. The operator/user will follow the instructions from the TSS1 program and may get help from the on-line help menu. The computer will boot up in the Boeckeler TSS1 Main window. If the user wants to exit the Boeckeler TSS1 program the user can do so by pressing the *Exit to Windows NT* button. The Boeckeler TSS1 is not fully automated and the operator will be asked to load slides into the carrier and make minor adjustments (focus).

3.3 Organization

The program is developed around screens. Each screen allows the user to only accomplish a few selected tasks. Further, the program as a hole is organized such that a user is directed down a path where only certain options are available to him. The options are selected in the Main TSS1 screen (the first screen). Each path selected in the main menu is designed to accomplish a task in either the single (local) station or multiple station modes of use. In the single station mode, the operator is interested in examining slides and making a diagnosis as quickly as possible while examining enough of the slide to be complete. In the multiple station mode, the operator is interfacing with another operator at another station operating in a consultant mode. In this case, each operator must respond to information requests coming in both directions. The requests take the form of files that are sent from one station to another using the ISDN phone lines. The requests appear the form of an electronic mail box where certain files will insert a message on the main menu (e.g., "Images Requested"). The operator is expected to see the request and respond by pressing the appropriate button on the main menu. After pressing the button, the user will be led down a path, screen by screen to fulfill the request. The use of the stations can be best seen graphically as in Figure 1 & 2. Figure 1 illustrates the single station mode where the examiner is just viewing the slides to make a diagnosis. Figure 2 illustrates a mode where a requesting station sends images to a consultant for examination.

The flow shown in Figure 2 is simplified into its most direct form. In some cases, the requesting station may send both the guide image and several high-mag images that the operator thinks are needed for a diagnosis. The consulting station may see everything he needs in the images that are sent and he can then send a diagnosis back to the requesting station eliminating many steps. Another scenario may entail several requests for high-magnification images that are needed for a complete diagnosis.

The final path involves only viewing old stored images and playing the sound files accompanying these images. A file server that shows the thumbnail images for each stored image is accessible using the *Single station recall old images* button on the main menu. After the thumbnail is viewed, the operator can view either the guide or accompanying high-magnification images in full size.

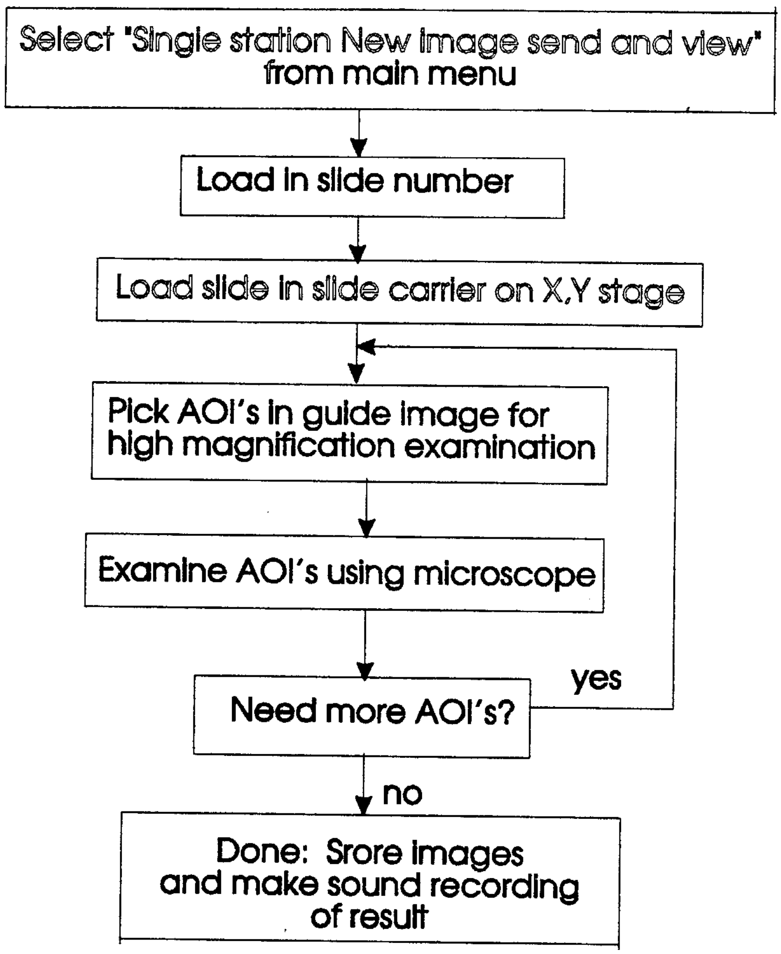


Fig. 1 - Single station (local) operation.

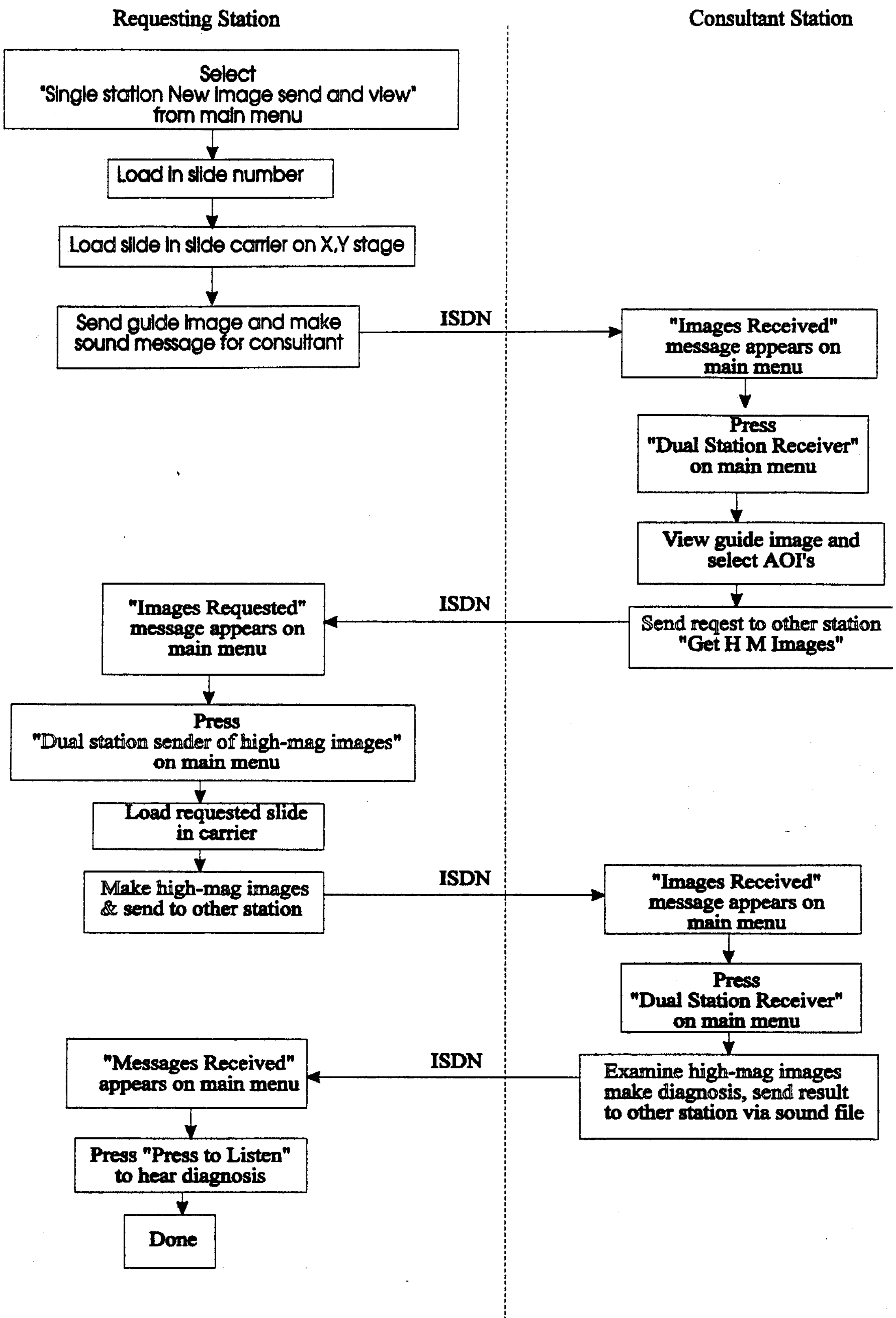


Fig. 2 - Multiple station operation.

3.4 Screen Operation Description

This section describes the operation of each of the screens and what happens with each of the buttons.

3.4.1 "Main TSS1 Window" Window

Synopsis:

This main menu controls the direction of the program. Pressing any one of the four main buttons puts the operator down a path to accomplish a task. The description of the paths are explained below under the button for each path. Messages will be displayed here when information from other stations have been received inviting the operator to act on those messages.

Operation:

"Single Station Recall Old Images"
This button will bring up a screen which will allow you to review stored guide and high-magnification images.

"Single Station New Image Send and View"
I) Examination: This button will let you scan a new slide to create a guide image. You can use that guide image to locate Areas Of Interest "AOI" and then direct the system to find those AOI's on the slide with the microscope. Thus, you can do a complete examination of the slide here.
II) Consultation: You can also prepare information to send to another station for consultation. This information will consist of the guide image, and may also contain high-magnification images and sound messages to accompany each of the image types. You can direct any or all of this information to be sent to another station.

Once received at the other station, a message "Images Received" will appear on their screen indicating that a consultation request has been received. If just a guide image was sent to another station for consultation, it is expected that the consultant will request one or more high-magnification images to be sent to them to aid in the diagnosis. After they receive the guide image and view it, they will select a number of AOI's and request you to make the requested high-magnification images. Their request, when it comes to your station, will have the program display the message "Images Requested" on the main menu. Your job then would be to use the "Dual Station Sender of High-Magnification Images" button and follow the directions indicated in the windows that follow. Once you have made the requested high-magnification images and sent them to the consulting station, that station will again display the message "Images Received". The consultant will press the "Dual Station Receiver" button to view the new high-magnification images. If they complete the diagnosis, they cab send a message back to you indicating the result of the examination. Your station will display the "Messages Received" sign with the "Press to Listen" button activated. You can press the button to listen to the result of the consultation.

"Press to Listen"
A sound message has been received from another station. The sign "Messages Received" will appear on the main menu with the button "*Press to Listen*" activated. The message should contain the diagnosis from a guide and set of high-magnification images sent for consultation.

"Dual Station Receiver"

This button will be activated when your station is requested to be a consultant on slide images sent to it by another station. The message "Images Received" will be displayed below this button. If you press this button, you will be guided through a process to examine the images sent to you from the requesting station. This process may include requesting more high-magnification images from AOI's that you have selected along with sound messages helping the requester obtain the needed information. The requester may have sent you a sound message accompanying either guide or high-magnification images. You may have enough images to make a diagnosis. in which case, you can send the result back to the requesting station via a sound message.

"Dual Station Sender of High-Magnification Images"

This button will be activated when you have been requested to make high-magnification image to aid in a consultation you have requested from another station. By pressing this button, you will be directed to load in a specified slide number and follow directions from the requesting station. The information from the other station will direct the microscope to examine AOI's where you will be expected to create and send the needed high-magnification images to the other station. You may receive a sound message to aid you in identifying what the consultant is wishing to examine.

"Exit to Windows"

This take you out of the program and into Windows NT. A warning message will appear to give you the choice to return here.

Usage:

Select an operation based upon your desires or the messages received from other stations. The program will guide you through the steps to accomplish the task you started here.

3.4.2 "Surgical Slide Entry Number" window

Synopsis:

This slide ID number gets tagged to all data allocated with this slide, including the guide image, all high-magnification images, message files, request files, etc. In addition, the ID-number will appear on each subsequent screen associated with this slide.

The files created from this slide will be stored on hard disk under a directory named the same as the slide ID number (e.g., C:\314567GID\314567.GID). High-magnification images will be stored under a sub directory (e.g., C:\314567GID\314567-01HIM\314567-01.HIM). Using the Windows file manager in NT, you can see the directory structure for each slide. This structure makes it easy to copy the entire data for each slide to a backup device such as the Syquest 270 Mb cartridge drive.

Operation:

"CLEAR"

If you need to change what you input.

"RETURN"

Will take you back to the main menu.

Usage:

You need to type in a six-digit slide identification number and press "OK".

3.4.3 "Load Slide in Carrier" window.

Synopsis:

You need to load the slide into the slide mount and press "OK". The slide should be oriented as shown below, with the information tag farthest away from you.

Make sure that the slide is securely positioned against the sides of the slide mount and parallel to its sides.

Operation:

"Return"
Will take you back to the previous screen "Surgical Slide Number Entry" window.

"OK"
Starts the scan of the guide image.

Caution:
The system, at this time, will not do a test to see of the slide is properly mounted in the carrier or even a slide is mounted in the carrier.

> NOTE: Damage to the scanner could occur if the slide is not mounted properly.

> NOTE: The slide must be clean and dry for a good guide image to be scanned. Make sure all debris is removed from the slide surface.

3.4.4 "Guide Image Display - Select for High Mag" Window

Synopsis:

This window displays the guide image that just scanned for examination. This means that you should look at the image and select which areas of interest "AOI" you need high-magnification images to make a diagnosis. The AOI you select will be written into a file and when you leave this window will direct the microscope to find for you to make a diagnosis.

Operation:

"Record Message"
Will record a recorded sound message to be stored with this guide image to describe what information is associated with it.

"Quit"
Will take you back to the main menu. A dialog box will appear informing you that this will take you back to the main menu and you will lose all the AOI's you have identified so far.

"Get HM Image"
Will have the system move the slide to the first AOI requested under the microscope. The requested information includes the location on the guide image and the magnification at that location. Up to 99 AOI's can be identified for each guide image. If no requests have been made and this key pressed, a dialog box will appear notifying you that no locations have been selected and bring you back into the window again.

"Record Image"
Stores the guide image on hard disk.

"Xmit G Image"
Stores the guide image on hard disk and transmits it to the other stations for examination. You should also record a sound message to send along with the image to indicate what the receiver is to look for in the image and to relay other important information concerning the image.

"Select Mags"
Brings up a display box that allows you to select the magnification for an AOI. You can select either a 2X, 4X, 10X, 20X, or 40X for each location. The size of the buttons for each magnification represent the area on the guide image that will be examined with the microscope.

"Guide Image"
The display of the guide image is only a small part of the full slide. To move the image around to see more of it, you can press on the guide image and the image will move in the direction you press from the center of the image. A smaller image (thumbnail) of the whole guide image is displayed in the upper right part of the window. The area seen in the large display is identified in the thumbnail with a colored box.

Usage:
Pick AOI's by moving around the display of the guide image until a region is seen where a high-magnification image is required. Press on the "*Select Mags*" and position the appropriate magnification over the AOI. Repeat until all AOI's are identified. Then press "Get HM Image" to start the examination with the microscope of the AOI's.

3.4.5 "High Magnification Image Window" Window

Synopsis:

This window displays a real-time high-magnification image for examination. You can move the slide around, change microscope objectives, save, and send the image. You can make a diagnosis from this slide, if desired, and make a sound file indicating the diagnosis, or send the image and sound file to another station for consultation.

Operation:

"*Record Message*"
Will record a recorded sound message to be stored with this high-magnification image to describe what information is associated with it. This message will be sent to another station along with the image if "*Send Image*" is pressed.

"Quit"
Will take you back to the main menu.

"Next Location"
This will move the microscope to the next high-magnification location you previously requested (Loc. will increment by one up to the # of Loc's as displayed in the window below the image.) If this is the last location, the program will take you back to the "Guide Image Display, Select for High-Mag" menu to select other AOI's if desired.

"Select New High-Mag Images"
This will take you back to the "Guide Image Display, Select for High-Mag" menu to select other AOI's if desired.

"Record Image"
Stores the high-magnification image on hard disk. A dialog box will ask you if you want to record a sound message to accompany this image.

"Send Image"
Stores the high-magnification image on hard disk and transmits it to the another station for examination. A dialog box will ask you if you want to record a sound message to accompany this image. The sound message sent along with the image should indicate what the receiver is to look for in the image and to relay other important information concerning the image.

"2X. 4X, 10X, 20X, 40X"
These button allow you to select the magnification currently being used with the microscopes.

"High Magnification Image"
The display of the high-magnification image is only a small part of the full slide. To move the image around, you can press on the high-magnification image and the slide will move so that the location you press will become centered in the display. A smaller image (thumbnail) of the whole guide image is displayed in the upper right part of the window. The area seen in the large display is identified in the thumbnail with a colored box.

"Focus"
This slider will allow you to focus the microscope. The speed of movement is scaled to the magnification used.

Usage:
You can move the slide around, change microscope objectives, save, and send the image. You can make a diagnosis from this slide, if desired, and make a sound file indicating the diagnosis or send the image and sound file to another station for consultation.

3.4.6 "Request to Load Slide" Window

Synopses:

You need to load the slide with the slide number requested into the slide mount and press "***O K***". The slide should be oriented as shown below, with the information tag farthest away from you.

Make sure that the slide is securely positioned against the sides of the slide mount and parallel to its sides. You will be directed to make the number of high-magnification images shown in the window for this guide image. After you load the slide and press "***O K***", the system will find the first location on the slide requested and position the slide under the microscope at that location and with the requested magnification. After you have made any necessary adjustments to position, focus, and magnification, you will press "***Send Image***". The system will then move to the next requested position and repeat the operation until all the requested positions have been sent.

If more than one set of high-magnification images have been requested for other guide images, the number of guide images requested will be output in the window. The above sequence will have to be performed for each of the groups of high-mag's requested.

Operation:

"Ok"
Press when the slide is loaded in the carrier. The system will move the slide to the first AOI identified for examination.

"Return"
Will take you back to the main window.

"Play Message"
Will play any message that was sent along with the request to help you in making the requested high-magnification images.

Usage:
The system, at this time, will not do a test to see of the slide is properly mounted in the carrier or even a slide is mounted in the carrier.

> NOTE: Damage to the scanner could occur if the slide is not mounted properly.
>
> NOTE: The slide must be clean and dry for a good guide image to be scanned. Make sure all debris is removed from the slide surface.

3.4.7 "Received Images" Window

Synopsis:
Allows the operator to view received guide and high-magnification images.

Operation:

"View Guide Image"
Takes the selected guide image and displays it in Screen 8.

"View High-Magnification Image"
Takes the selected high-magnification image and displays it in Screen 9.

"Quit"
Takes you back to the main menu.

Usage:
When the screen is called up, a list of all the received guide images will be displayed on the left window "Guide Images". If one is selected by pointing to the file name, a thumbnail of that guide is displayed in the "Guide Image" window. Also, any high-magnification image files that were stored that accompany that guide image will be listed in the right window "High Mag Images". If one of the high-magnification files is selected by pointing to the file name, a thumbnail of that high-magnification is displayed in the "High-Mag Image" window. Either the guide or high-magnification image can be displayed in a full screen by pressing either "View Guide Image" or "View High-Mag Image".

3.4.8 "Guide Image Display - Select for High Mag" Window

Synopsis:

This window displays the guide image that was send from another station for examination. This means that you should look at the image and select which areas of interest "AOI" you need high-magnification images to make a diagnosis. The AOI you request will be written into a file and sent to the other station to have the high-magnification images made and sent back to you.

Operation:

"Play Message"
Will play a recorded sound message from the other station, if one was recorded. This information may help you in making the diagnosis and picking AOI's.

"Quit"
Will take you back to the main menu. A dialog box will appear informing you that this will take you back to the main menu and you will lose all the AOI's you have identified so far.

"Get HM Image"
Will send the requests for AOI's to the other station. The requested information includes the location on the guide image and the magnification at that location. Up to 99 AOI's can be identified for each guide image. If no requests have been made and this key pressed, a dialog box will appear notifying you that no locations have been selected and bring you back into the window again.

"Select Mags"
Brings up a display box that allows you to select the magnification for an AOI. You can select either a 2X, 4X, 10X, 20X, or 40X for each location. The size of the buttons for each magnification represent the area on the guide image that will be examined with the microscope.

"Guide Image"
The display of the guide image is only a small part of the full slide. To move the image around to see more of it, you can press on the guide image and the image will move in the direction you press from the center of the image. A smaller image (thumbnail) of the whole guide image is displayed in the upper right part of the window. The area seen in the large display is identified in the thumbnail with a colored box.

Usage:
Pick AOI's by moving around the display of the guide image until a region is seen where a high-magnification image is required. Press on the 'Select Menu and position the appropriate magnification over the AOI. Repeat until all AOI's are identified. Then press "Get HM Image" to send the request to the other station.

3.4.9 "High Magnification" Window

Synopsis:

This window displays a high-magnification image that was send from another station for examination. The region in the guide image where this image is located can be seen in the thumbnail of the guide image in the upper right corner of the window. Information about the location and magnification used to create the high-magnification image are located in an information window below the image.

Operation:

"Play Message"
Will play a recorded sound message from the other station, if one was recorded. This information may tell you what the sender did to make the image and what he may want you to know about the image.

"Return"
Will take you back to the "Received Images" menu to pick another guide image to review.

"Record Message"
Will allow you to record a sound message associated with this high-magnification image. The message will be sent back to the other station requesting the examination and should contain the diagnosis and other relevant information concerning the slide.

"Next Location"
This will move the microscope to the next high-magnification location you previously requested (Loc. will increment by one up to the # of Loc's as displayed in the window below the image.) If this is the last location, the program will take you back to the "Received Images" menu to work on another guide image and associated high-magnification images set. If no other guide images have been received, the program will take you back to the main menu.

Usage:
Review this and other high-magnification images you previously requested for this guide image and make a diagnosis. The diagnosis can be written into a sound file by pressing the "Record Message" and it will be sent back to the other station.

3.4.10 "Stored Images" Window

Synopsis:
Allows the operator to view stored guide and high-magnification images.

Operation:

"View Guide Image"
Takes the selected guide image and displays it in Screen 11.

"View High-Magnification Image"
Takes the selected high-magnification image and displays it in Screen 12.

"Quit"
Takes you back to the main menu.

Usage:
When the screen is called up, a list of all the stored guide images will be displayed on the left window "Guide Images". If one is selected by pointing to the file name, a thumbnail of that guide is displayed in the "Guide Image" window. Also, any high-magnification image files that were stored that accompany that guide image will be listed in the right window "High Mag Images". If one of the high-magnification files is selected by pointing to the file name, a thumbnail of that high-magnification is displayed in the "High-Mag Image" window. Either the guide or high-magnification image can be displayed in a full screen by pressing either "View Guide Image" or "View High-Mag Image".

3.4.11 "Display of Stored Guide Image" Window

Synopsis:

This window displays the guide image that was stored from a previous examination. You can move the image around to see various parts of the guide image and play a sound message associated with the guide image.

Operation:

"Play Message"
Will play a recorded sound message, if one was recorded.

"Return"
Will take you back to the "Stored Images" menu to select other guide or high-magnification images.

"Guide Image"
The display of the guide image is only a small part of the full slide. To move the image around to see more of it, you can press on the guide image and the image will move in the direction you press from the center of the image. A smaller image (thumbnail) of the whole guide image is displayed in the upper right part of the window. The area seen in the large display is identified in the thumbnail with a colored box.

Usage:
Only used to review stored guide images.

3.5 Technical Specifications:

High-resolution image (guide image)

CCD linear array	Kodak KLI-4103
Resolution	4104 x 3 pixels, 12 uM
Clock rate	1.0 mHz
Acquire	2900 x 2048 x 24 bit color
Display	2900 x 2032 x 24 bit color
Acquisition time	8.5 seconds
Compression time	30 seconds
Compression ratio	variable through software
Illumination	preset

High-magnification image

CCD area array	Sony DXC-960MD-(3-chip color)
Resolution	768 x 494 pixels, 9 uM
Display	768 x 484 image points
Acquisition time	33 mSec
Compression ratio	variable through software
Field of view	match optical resolution

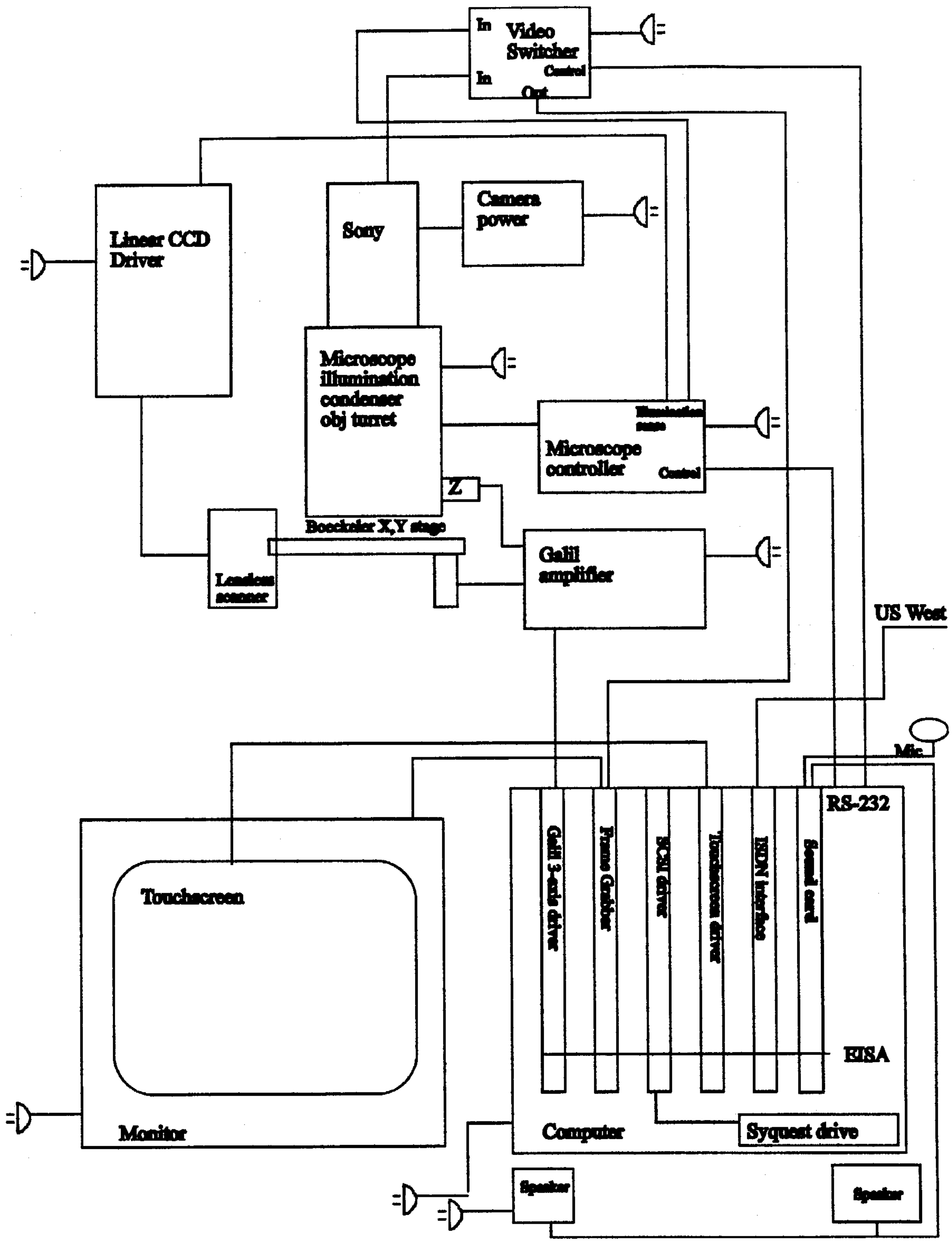
Microscope

X,Y stage	124mm x 55mm travel, computer control with manual override via touchscreen
Focus	computer control of fine focus with manual override via touchscreen
Magnification	computer control with manual override via touchscreen
Condenser	computer control
Illumination	computer control with manual adjustment of correct value
Objectives	2X, 4X, 10X, 20X, 40X, plan apochromat
Eyepieces	10X, 20mm FOV

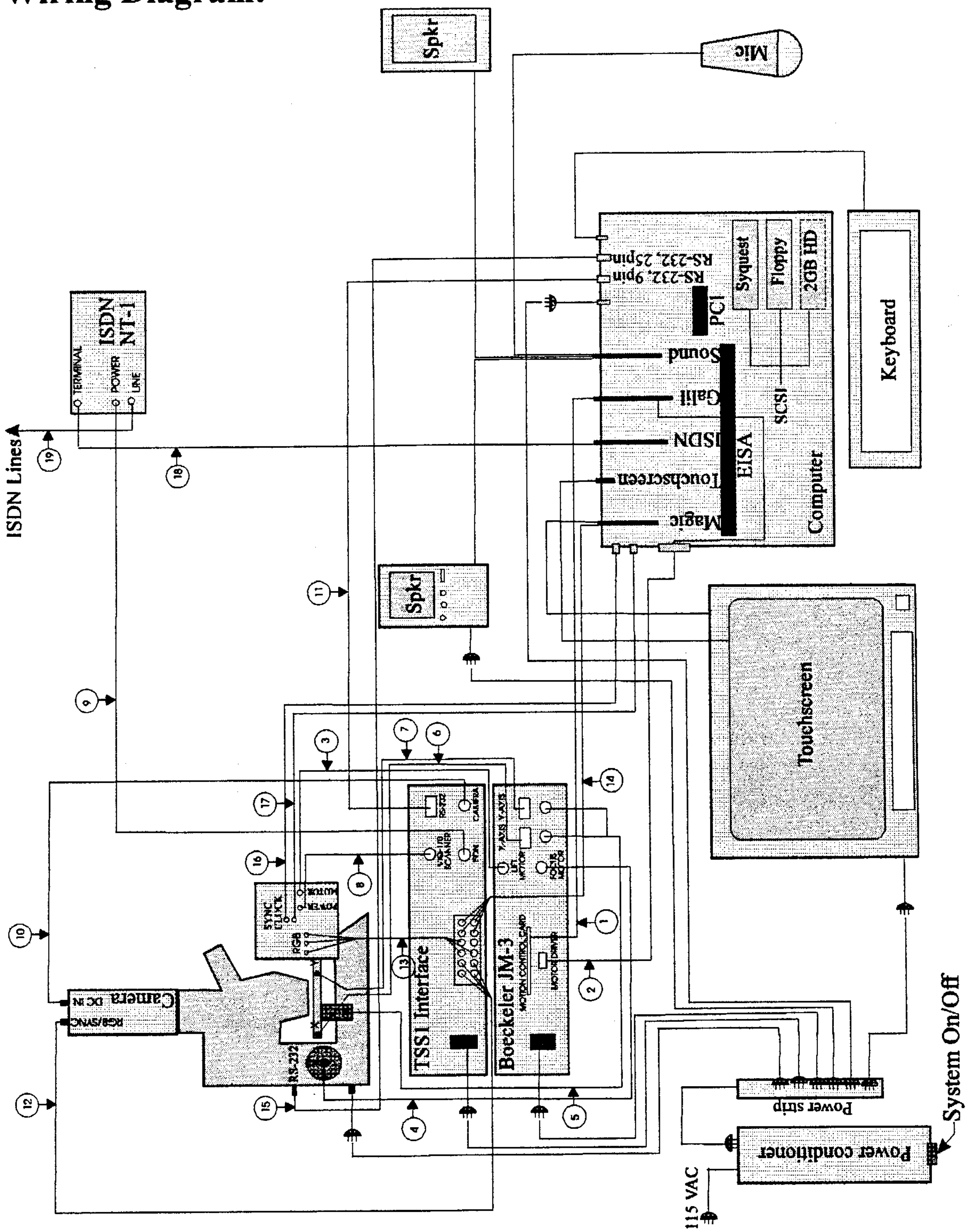
Computer System

CPU	Pentium, dual 90 MHz Intel processor
Tower	Full sized tower configuration
Driver controller	SCSI onboard controller
Fixed storage	2.0 Gbyte
Removable storage	270 mByte removable disk (Syquest)
Monitor	1280 x 1024, 17 inch touchscreen
Floppy drive	1.44 MB, 3.5 inch
Keyboard	101 keyboard
Data compression	JPEG compression via software algorithm
Frame grabber	Matrox Magic/RGB for both cameras (video switcher)
Transmission card	ISDN with two lines of 56 Kbits each
Printer	N.A.
Memory	64 MB RAM
Cache	512 KB
Slots	3 slots PCI bus 5 slots EISA bus
Ports	2 serial RS-232; 1 parallel
Graphics accelerator	Matrox Magic/RGB, 1024 X 768 X 256 colors
Power supply	300 W
Operating system	Microsoft Windows NT 3.50
Software language	C++, v. 2.20

Hardware Block Diagram:



Wiring Diagram:



4. HOSPITAL INFORMATION SYSTEMS

The purpose of this section of is to review state-of-the-art Hospital Information Systems, both for the military and civilian arena.

4.1 Hospital Information Systems

The HIS (Hospital Information System):

- manages hospital finances and resources
- furnishes decision support[1] through ad-hoc reporting
- automates office work at all levels
- tracks/manages patient data, care and billing
- establishes inter-communication and data-exchange between:

  other hospitals, insurance and billing agencies, clinics, laboratories, nursing stations, other information systems and data repositories, wired or wireless instrumentation and printers, technologists, and physicians in the hospital or elsewhere.

However, current HIS are not what would be termed state-of-the-art. As pointed out in the recent edition of the New York Times, describing a leading medical institution, namely, Stanford Medical Center (California), "...when new patients enter the hospital, their medical information is recorded and distributed much as it was 30 years ago: on paper.

"As primitive as that may sound Stanford is actually ahead of most hospitals in adopting new information technology. It has dozens of computer systems and has more than 70 clinics, and about three years ago the hospital embarked on an ambitious program to link them in a common system...

"...To Gerry Shebar, Associate Director of Information Management and Technology for Stanford Health Services, the program makes Stanford something of a leader. The health care industry, he said, is 'where banking was 10 years ago, and the airline industry was 15 years ago - pretty much paper-based.'

"...so the broad changes underway in health care are creating a huge market for new technology.

"Hospitals...have gone through waves of computer purchases. Many individual physicians have bought personal computers, if only to aid their staff in pursuing reimbursement from insurers and Medicare.

"But these computers have been unable to communicate with each other, so any given bit of medical or financial information remained accessible to only a few individuals. And that most critical of documents, the patient record, lived on in paper form."

Thus, the purpose of this Section is to review the state-of-the-art of HIS, both for the military (Subsection 4.5) and the civilian arena (Subsection 4.6). By means of this review Kensal staff, who are engaged in modernizing conventional microscopy for pathology, will be aware of

the environment in which such new devices must operate. This will have an impact on the structuring of the associated hardware and software systems.

4.1.1 HIS Modularization

Since more feature-sets and end-users have been added to the HIS domain over the years, the HIS has become increasingly modular with outgrowths in clinical and laboratory information systems (CIS/LIS). *Savings* through better organization, increased automation, and faster order/result turnaround are the compelling reasons for outgrowth and modularization. Each sub-IS module not only acts as a store-and-forward/fault-tolerant repository of data between the central HIS[2], but also provides domain-centric ad-hoc feedback to inquiring administrators who must report to hospital enterprise leaders and government regulating agencies. The six related and overlapping systems[3] within the health care field are:

- Management Information Systems
- Financial Information Systems
- Telemedicine Information Systems
- Knowledge Systems
- Public Health Information Systems
- Research Systems

4.1.2 HIS Security

Throughout the chain of hospital rank and command, layered need-to-know based security protects sensitive information within the HIS. While nursing stations can prepare work lists based on patient needs, they cannot view executive level reports. While the admissions-desk can see bed availability in real time, they can not change laboratory results. While physicians can submit pharmaceutical and laboratory orders, they cannot admit, discharge, or transfer (ADT) patients. Security is necessary to protect patient privacy, control efficiency and order as well as prevent accidents, fraud, or deliberate reprisals and sabotage against the hospital enterprise.

4.1.3 Strategic Planning

The HIS, when well implemented, can be used as a powerful management tool to guide decision making. The ideal HIS provides rich insight and decision support for the optimal financial structuring of the hospital.

In the near future, civilian HIS will likely be linked to a Community Health Information Network (*CHIN*) to help minimize costs within a group of collaborating health-care providers. In addition, research by the NII-HIN Consortium is underway to develop standards to provide transparent linkages between CHINs through a national information infrastructure. Finally, there is some movement towards a Global Heath Network which is focused on the critical role of prevention in reducing health care costs through rapid, accurate transmission of information. Other innovation includes computer-based order/results entry and point-of-care reporting.

"CHINs are community-wide electronic networks of health care providers, medical facilities, payers, pharmacies, and other health care support companies that allow the sharing of patient medical and financial data in a more efficient manner. CHINs can also support the sharing of radiological images and live telemedicine. A regional CHIN promises to improve the quality of patient care and lower the cost of health care in the community." Before a hospital can be integrated into a CHIN however, it must support a *Computer-based Patient Record* (CPR)[4] that

can be transparently passed to other hospital HISs of likely dissimilar implementation. Recently, enormous industry and media attention have been focused on the CPR. Despite this, hospitals in general are hesitating to implement a CPR due to cost and complexity. CHINs are thus just emerging in the health care industry but will play a significant role in the near future of health care.

4.1.4 Computer-based Patient Record (CPR)

The CPR concept is fundamentally a computer-stored collection of health information about one person linked by a person identifier. The CPR or the "electronic patient record" are terms used by vendors interchangeably but refer to different levels of computerization. Clarification regarding these levels has been outlined by the Medical Records Institute[5] (MRI), founded on the principle that the future of health information technology lies in the successful creation and implementation of electronic health record systems. Although in fact *five levels* have been defined, only the first two levels have been achieved--levels 3 through 5 are not felt to be possible for some time. The five distinct levels of computerization for patient information systems has been outlined by MRI as follows:

- Level 1: *Automated Medical Records*
  Are paper-based medical records with as much as 50% of the printed content computer generated. Level 1 automation within the hospital environment is focused around the following functions:
  - ADT (Admission/Discharge/Transfer) systems
  - Improved capture of patient information through digital dictation systems
  - Patient accounting and its linkage to clinical information
  - Departmental systems (i.e., Radiology Information Systems, Laboratory Information Systems, Pharmacy Information Systems, etc.)
  - Order Entry/Results reporting

  Other innovation parallel to the paper-based medical record are nursing/bedside computing (discussed in section 1.5), implementation of an enterprise-wide master patient index, the linkage of various parts into an enterprise-wide network, the development of interface engines (discussed later), and imaging.

- Level 2: *Computerized Medical Record System*
  Level 1 automation does not solve the space shortage in record storage, nor create an electronically available record. A level 2 computerized-medical record system (or document imaging system) allows paper-based medical records to be created, then scanned, and indexed within a computer system with the same automation functions as level 1. Optical Character Recognition (OCR) or Intelligent Character Recognition (ICR) do not fit into level 2 automation since the scanned documents are stored on optical disks as unchangeable images, not ASCII-based data-sets. Level 2 is the only method in existence as of this writing to computerize the medical record in a paperless system.

- Level 3: *The Electronic Medical Record*
  The level 2 computerized medical record has basically the same structure as the level 1 paper-based medical record. The level 3 electronic medical record has the same scope of information in level 2 but the information is rearranged for computer use. While the level 1 paper-based records system is a passive storage device, level 3 can provide interactive aiding of the decision making process by knowledge coupling, providing decision support, and many other functions. Level 3 requires a secure enterprise-wide infrastructure for appropriate capture, process and storage of patient information.

- Level 4: *Electronic Patient Record Systems (also called Computer-based Patient*

Record Systems)
The patient record has a wider scope of information than the medical record. It combines several enterprise-based electronic medical records concerning one patient and assembles a record that goes beyond the enterprise-based retention period.

o Level 5: *The Electronic Health Record*
The more comprehensive collection of an individual's health information is the level 5 electronic health record. It differs from the electronic patient record in the unlimited amount of health information captured by care givers regarding a person. It includes wellness information possibly captured by the individual or parents, therapists, etc., including data for example on behavioral activities such as smoking, exercising, dietary and drinking habits. The electronic health record is maintained through the cooperation between the individual who controls his or her health information, and the care giver.

4.1.5 Computer-based Point of Care

A recent HIS appendage and innovation for cost-savings *are computerized point-of-care systems*. HIS vendor CPSI markets a "Chart Cart"--a portable PC on a medicine-cabinet cart with a touch sensitive screen and bar code reader, all wirelessly connected to the HIS--which allows Nursing Services personnel to enter information into the HIS at the patient bedside. Clerical functions are automated and duplicate entry of information into nursing documents is eliminated. Charges for administered medication can be billed immediately by using the keyboard and bar code reader to scan the medication container.

MEDITECH also has a 14 ounce hand-held personal data assistant (PDA) for computer-based point of care. End users of this device are nurses, nurses aides, and therapists. The PDA holds data for 10-20 patients and keeps track of the "whereabouts of physicians". When a nurse's shift begins, the nurse downloads patient records into the PDA and then administers to the need of the patients. During the shift, the nurse can operate the PDA with one hand's thumb--to see orders and record results--while administering care with the other hand. After the shift, the data in the PDA is uploaded into the HIS.

4.1.6 Health Care Information System Priorities

Relatively new (and growing) in the HIS outgrowth are multimedia systems, wireless LAN technology, mobile Personal Data Assistants (PDAs), and telemedicine. The current priority however among health care providers today is "integrating systems across separate facilities", which outranks, "implementing a computer-based patient record, reengineering to a patient-centered computing environment, and incorporating wireless/portable devices".

In a January 1995 health-care survey of nearly 1000 respondents, "HIS budgets will grow at a healthy clip: more than 80% say HIS budgets are going up. Over half stated that budgets would increase 30% or more." The surveyors thought that these statistics reflected a growing concern to integrate health care networks. Thus, many existing HIS implementations still lack enterprise-wide integration.

4.1.7 Computer Imaging In HIS

Computer imaging is relatively new to the HIS. Several outgrowths are currently integrating images and text in stand-alone modules (i.e., radiology, paperless-office, and telemedicine modules). However, there is no standard way to integrate the text-based medical record and related digital image-based entities together for call-up throughout the HIS, much less across hospitals or CHINs. Thus, a tremendous amount of work yet lies ahead to create, what might be coined as, the "Graphical Patient Record" (GPR).

While standards do not exist yet meshing text and large binary objects like images for HIS-wide access, Los Alamos National Laboratories (LANL) has recently announced TeleMed which contains an experimental GPR focused currently in teleradiology. TeleMed, based on a distributed national radiographic and patient record repository which could be located anywhere in the country, is designed to assist doctors in treatment planning through viewing patient treatment histories and associated radiographic data. This data can be viewed simultaneously by users at two or more distant locations for consultation with specialists in different fields. LANL claims that TeleMed "is the first to provide transparent access to patient record components over a WAN, building the complete patient record from various partial records and displaying that in an integrated manner to the healthcare provider."

Industry standards are needed for seamless integration of images throughout the HIS. Once again, no standard exists which integrates text and images across the entire HIS as of this writing; however there are several SDO's (Standards Developing Organizations)--who have good foundations and the technical resources--developing such a standard. (See below.)

4.1.8 Reports Available From The HIS

Available HIS reports are endless and their titles vary from vendor to vendor. Often, vendors will tailor report content and structure to the needs of the hospital. Thus, unlike the IRS or other government branch, there is little report standardization, except in the insurance billing modules and in the reports destined for accreditation overseers.

Often provided in the various HIS modules, is the ability to generate ad-hoc reports; thus, in addition to the "canned" reports. Reports of any content or structure can be generated through SQL (Structured Query Language) inquiries on a database. However, the HIS end-user must learn how to use the SQL interface and the semantics of the query language before useful reports can be generated.

As mentioned earlier, an extreme interest in moving to a paperless reporting mechanism has been manifest in many hospital enterprises, due to cost savings. Most of the HIS vendors are just now beginning to offer the "Level 2" document imaging ability. "Level 3" is highly desired, but requires physical and logical integration across disparate facilities and computer systems, with nearly a unique solution for each integration case. To understand the barriers to enterprise-wide electronic report exchange, the physical and logical architecture of the HIS will be discussed in the next section.

4.1.9 Standards

There are many standards groups who's specifications are being used to implement the HIS. At the *messaging level*--the level where HIS nodes exchange information related to the health-care industry--various standards groups, many driven by HIS vendor innovation, have been working together to build the expanding field of *medical informatics*. At the lower hardware level, IEEE, ISO, ITU-T (CCITT), ANSI, et al, have published networking specifications in circulation for years, used in HIS implementation. Newer negotiated-multiband technologies such as ATM[6] (Asynchronous Transfer Mode) for information interoperability are also being used in some HIS implementations.

4.2. Medical Informatics

"Biomedical Informatics is an emerging discipline that has been defined as the study, invention, and implementation of structures and algorithms to improve communication,

understanding and management of medical information. The end objective of biomedical informatics is the coalescing of data, knowledge, and the tools necessary to apply that data and knowledge in the decision-making process, at the time and place that a decision needs to be made. The focus on *the structures and algorithms necessary to manipulate the information separates* Biomedical Informatics from other medical disciplines where information content is the focus."

A medical informatics USENET newsgroup is open to the Internet public at:

sci.med.informatics

4.2.1 Medical Informatics Standards Groups

The term "standards"[7] includes standards developed by accredited standards organizations and other categories of organizations who are affecting, or working on, technical, procedural, and systems standards, guidelines, professional protocols, minimum requirements, as well as industry practices necessary to enable the computer-based record system of the future to function. From this perspective, there are seven categories of organizations involved in the process:

- Major standards organizations who develop application standards for health care
- Professional societies involved in standards creation
- Trade associations
- Government organizations
- Industry consortia
- National players
- Standards organizations for base standards

The Medical Records Institute[8] provides an *International Directory of Organizations: Standards and Developments in the Creation of Electronic Health Records* [9] which lists over 160 different groups working on standards in health care throughout the world; outlining their current projects, publications and reports.

One of the largest components in the HIS standards work in progress is the design effort taking place to specify how digital messages should be exchanged between HIS computer systems and what they should contain. These messages encapsulate information ranging from ADT updates to lab-results data. The messaging structures implemented in HIS systems today are analogous to the different foreign languages and/or dialects spoken in various regions of the earth--from the global HIS market perspective, every vendor has its own unique standard or, more frequently, *interpretation* of a local recognized standard (i.e., HL7, discussed later). Since a substantial technical investment is required to enable one vendor--faced with appending modules on to HIS systems from other vendors--to speak all these languages and dialects, convergence to a common language--or messaging standard--is the drive behind the messaging SDOs today.

4.2.1.1 The Message Standards Developers Subcommittee (MSDS)

In 1991[10] there were at least six organizations developing health care messaging standards, of which three were accredited by the American National Standards Institute (ANSI). During that year, the European standards agencies asked ANSI to clarify with whom they could coordinate health informatics standards. As a result, ANSI formed the Health Informatics Standards Planning Panel (HISPP) to coordinate the development of health informatics standards. HISPP's membership includes system vendors, professional organizations, Standards Developing Organizations (SDOs), and various users of standards.

In turn, HISPP formed a subcommittee of its members who were standards developing organizations. This is the Message Standards Developers Subcommittee (MSDS). The members of MSDS are SDOs developing health care message interchange standards. The objective of the MSDS is to achieve harmonization of the standards that SDOs develop.

Members of MSDS are:

- **ASTM**: American Society for Testing and Materials
- **DICOM**: Working groups of American College of Radiology (ACR) and National Electrical Manufacturers Association (NEMA)
- **HL7**: Health Level Seven
- **IEEE**: Institute of Electrical and Electronics Engineers Medical Data Interchange Working Group
- **NCPDP**: National Council of Prescription Drug Pharmacies
- **X12N**: Insurance Subcommittee of ASC X12

The MSDS formed the Joint Working Group for a Common Data Model (**JWG-CDM**) as an open standards effort to support the development of a common data model that can be shared by developers of health care informatics standards. The IEEE Committee has secretariat responsibility for the activities of the JWG-CDM. Thus, for all practical purposes, the IEEE Medical Data Interchange Working Group and the Joint Working Group for a Common Data Model are identical. The acronym JWG-CDM refers to these groups.

On June 6, 1994 the IEEE Standards Department made available the initial draft of the JWG-CDM standard as four postscript documents.

Duke University, North Carolina, maintains a repository for MSDS electronic files at:

(WWW) http://dumccss.mc.duke.edu/ftp/standards.html
(FTP) dumccss.mc.duke.edu

In addition, DICOM maintains electronic information at:

(FTP) xray.hmc.psu.edu

4.2.1.2 Health Level Seven (HL7) - Background

HL7 was founded in 1987 to develop standards for the electronic interchange of clinical, financial and administrative information among independent health care oriented computer systems; e.g., hospital information systems, clinical laboratory systems, enterprise systems and pharmacy systems.

In the last three years, its membership has tripled to over 1,400 hospital, professional society, health care industry, and individual members including almost all of the major health care systems consultants and vendors. The HL7 standard is supported by most system vendors and used in the majority of large U.S. hospitals today. It is also used in Australia, Austria, Germany, Holland, Israel, Japan, New Zealand and the United Kingdom.

Currently, HL7 does not support images but is working with the ACR to merge the DICOM standard with HL7 for image support. As of this writing, the current version of HL7 is v2.2; image support will not be available until v3.0, which is due in 1996.

HL7 minutes, standard drafts, and sample source-code are available through Internet FTP servers on [dumccss.mc.duke.edu], WWW URL:

http://dumccss.mc.duke.edu/ftp/standards.html

Also supported is a discussion group on the HL7@Virginia.EDU list server.

Virtually all HIS vendors are HL7-compliant and most of the world, including the military, is merging their HIS systems and sub modules into this standard. However, each vendor's implementation of HL7 is somewhat different--a unique interpretation. Thus, while HL7 provides a strong measure of order to the messaging dilemma between HIS systems and sub-modules, it doesn't eradicate all communication problems. Interfacing two HL7-compliant systems, for example, requires much work on a technical level.

4.2.2 Data Interface Engines

Because of the complexity involved in interfacing modules to HIS systems, each with its own interpretation of a recognized messaging standard, many system integrators are turning to "data interface engines" to simplify the process.

Interface engines (IEs) are a complex middleware technology also known as integration engines, interface hubs, and application interface gateways. Typically, an IE is a separate computer which acts to transform[11] messages between other computer systems and their applications. These disparate applications must have the ability to exchange messages, for example through a messaging application programming interface (API).

In the hospital environment, such IEs are used between HIS modules (i.e., the ADT module and the Radiology Module) perhaps purchased through different vendors[12] with different hardware/software implementations. The benefits of using an IE include, 1) simplified HIS interface development since the IE is a tool-set designed specifically for that purpose, 2) centralized interface management capabilities (i.e., starting, stopping, monitoring, trouble-shooting), 3) superiority over point-to-point (PTP) interfaces since complexity is reduced through use of the centralized IE hub (i.e., if 5 different systems requiring bilateral interfaces need to interoperate with each other, 20 PTPs are needed, while only 10 interfaces are needed to an IE-based implementation--adding another node to the former requires 10 more PTPs while the later only 2 interfaces), 4) possible reduced costs for IE-based interface implementation when compared to paying application vendors for installing a PTP-based interface, 5) the ability to populate clinical data repositories or data warehouses by routing data from messages exchanged between other applications, 6) an established CHIN entry-point for an organization.

IEs ideally send messages following the HL7 standards. However, some EDI[13] transaction sets, and ASTM[14] messaging standards are also used. Further informaiton on networks for HIS is given in Appendix A.

4.3 U. S. Military HIS

The US military has standardized its HIS installations around the world through the Composite Health Care System (CHCS), developed by SAIC. (The Veterans Administration uses the Decentralized Hospital Computer Program (DHCP), developed for the VA hospitals.

4.3.1 Science Applications International Corporation (SAIC) Overview

Science Applications International Corporation (SAIC), a privately owned defense contracting company headquarted in San Diego[15] with 19,000+ employees nationwide, enjoyed $1.9 billion in revenues for FY94 with 86% coming from the federal government. Outside the national security community, few have heard of SAIC.

Founded in 1969 by J. Robert Beyster[16], SAIC's principal product is brainpower. It acts as a systems integrator to design solutions to the government's toughest technology problems. SAIC's past projects include designing one of the early "star wars" antimissile defenses, the FBI's computerized fingerprint-identification system, and plant monitoring equipment for power plants. SAIC has also designed and built the <u>largest hospital information system in the world</u> as well as the <u>largest medical telecommunications system in the United States</u>[17]. Recently, in a <u>telemedicine</u> experiment, SAIC helped link physicians aboard a hospital ship off the coast of Haiti with major U.S. military hospitals. As a result, the ship's doctors were able to give U.S. soldiers better medical treatment. Finally, SAIC's newest DoD health care contract involves building <u>community networks</u> linking military medical facilities with civilian providers and VA medical centers.

4.3.2 SAIC's Composite Health Care System (CHCS) Program

The mission of the Department of Defense (DoD) health care system[18] includes maintaining the health status of the military force (including family members and retirees and their family members) by providing cost-effective, high quality inpatient and outpatient medical and dental care and maintaining medical readiness to support mobilization. It includes all inpatient medical facilities and all significant outpatient facilities, to include care delivery in the military theater and veterinary services.

Medical data processing capabilities are being acquired to assist the health care providers and administrators in the management and delivery of quality care to the patient population served within the DoD health care system. A flexible solution is being provided in medical data processing capabilities for all DoD medical treatment facilities (MTFs). Both large and small MTFs will be supported via a standard Composite Health Care System (CHCS). The architecture design involves an integrated hardware and software solution, fully scaleable to the range of DoD medical facilities, from small stand-alone facilities to large regions and outpatient catchment areas (OCAs).

4.3.3 Description of CHCS

The Composite Health Care System is funded through a $1.1 billion contract, SAIC's largest program. CHCS fundamentally is an automated network handling military health care, including patient scheduling, admissions, prescriptions, lab tests, and record keeping and was developed from close cooperation between the Pentagon and SAIC. CHCS has been installed in over 600 medical facilities worldwide and is also used in mobile units such as the one deployed in Gutanamo Bay, Cuba (discussed later in section 5.6).

The CHCS is a fully integrated, automated information system that supports the administration and delivery of health care in MTFs. The integration of this information system means that all data about a patient need only be entered once, authorized users have access through the system to all data needed to perform their functions, and all functions are available to authorized users.

The current functional baseline supports the following areas:

- Registration of patients into one database
- Eligibility (DEERS) checking
- Patient Appointment and Scheduling (PAS)

Patient Administration (PAD)
Nursing
Inpatient and Outpatient Order Entry and Results Reporting
Pharmacy
Laboratory
Radiology
Clinical Dietetics
Quality Assurance
Medical Services Accounting
Electronic Mail
Integration with other standard DoD and Military Department automated information systems

Pre-Planned Product Improvement (P3I) for CHCS includes those data specific to individual patients that are most cost-efficiently captured and stored along with all other elements of the patient's electronic record, but that are not part of the original functional baseline of CHCS. These data derive largely from the Managed Care Program (MCP), including such things as other health insurance, enrollment data, and third party collection support. The life cycle cost and benefits of automated information system (AIS) support for these data will be derived from functional economic analysis.

The major technical design objectives are:

Ease of use;
Minimal program risk;
Ease of maintenance;
Flexible system configurations to support future enhancements;
Ease of operation;
Appropriate system security;
Scalability (small to large);
Reliability and Availability greater than 99%, and;
Adequate performance from user perspective.

4.3.4 History Of CHCS

Feb 79
MILESTONE 0: Mission Element Needs Statement (MENS) approved

1981
Initial Operating Capability (IOCs) systems (TRIPHARM, TRILAB, TRIRAD, and TRIPAS) deployed until an "integrated" system could be developed
Contracts let would expire in 8 years

Dec 84
MILESTONE 1: Major Automated Information Systems Review Council (MAISRC) approved CHCS requirements

Sep 86
Four (4) vendors selected to test CHCS software development and deployment with one of the vendors having to use the VA-DHCP software
- Baxter Travenol to Sheppard AFB, TX
- McDonald Douglas to Camp Lejeune, NC
- SAIC (with VA-DHCP) to Ft Knox, KY
- Technicon Data Systems (TDS) to Jacksonville, FL

Tri-Service Micro Pharmacy Systems (TMPS) deployed as part of TRIPHARM contract

Mar 87

Development/deployment to test sites started. Vendors had one year to develop and deploy CHCS to their respective sites TDS dropped out of the competition

Mar 88

MILESTONE II: SAIC selected as prime vendor for CHCS

Jul 88

SAIC to deploy CHCS to eight (8) additional "beta" sites the current software running at

Ft. Knox

Development of additional functionality would continue at Ft Knox. The beta sites, however, demanded any new functionality that was developed at Ft Knox be provided to them.

Milestone III set for Jul 89

New beta sites

- Air Force
  - Keesler AFB, MS
  - Sheppard AFB, TX
  - Eglin AFB, FL
- Navy
  - Camp Lejeune, NC
  - Jacksonville, FL
  - Charleston NB, SC
- Army
  - Eisenhouer, GA
  - Nurenberg, GE

Nov 88

SAIC was unable to deploy to new sites and deploy new functionality at the same time. Startup problems caused the CHCS program to be "frozen" for 3 months until software got back under control. This led to software version 2.0 or better know as the "Knox Baseline"

Milestone III delayed to Dec 89

Jan 89

Deployment restarted at beta sites

Oct 89

In Process Review (IPR) by MAISRC

- GAO stated that the current beta sites did not represent the largest nor smallest DoD hospitals and did not test the capability of CHCS to support readiness
  - Walter Reed and Bethesda added as representatives of the largest DoD hospitals
  - Shaw added as representative of DoD smallest hospitals
  - Carswell added to test readiness capability
- With multiple services using CHCS on a single host like in Hawaii, DoD was required to develop software to support "divided work center" areas. The divided work center (DWC) software would be ready for Version 3.0
- Tripler and Hawaii added as alpha site to test DWC software
- Milestone III delayed to Oct 90
- Support contracts for IOC systems expired Sep 89

1990

- Funding became a problem
- Carswell and Bethesda were removed as beta test sites
- Contracts for IOC systems had to be extended
  - As an interim, only enough CHCS functionality would be deployed to replace the IOCs (IOC-R Program). Software Version 4.0 would provide enough capability to replace the IOCs
  - Congressional language for FY91 for IOC-R
    - "The Secretary may not authorize the use of CHCS to replace an IOC in any MTF that is not involved in the OT&E phase....until the Secretary certifies to the Committees on Armed Forces of the Senate and House of Representatives that the use of CHCS is the most effective method for maintaining automated operations at the facility"
  - Congressional language defining certification
    - "Software to be used in a given MTF must be successfully tested at a representative MTFs"
    - "Software must be stable and all critical system incidents must be eliminated"
    - "The hardware must be properly sized at that facility to ensure adequate capacity when full configuration is installed"
    - "Installation of the IOC-R system must not adversely effect SAIC's capability for continuing OT&E"
  - Malcolm Grow added as test site for IOC-R software
- CHCS sites have performance problem
- MAISRC approved the Standard Appointing and Scheduling System (SASS) deployment
- Milestone III delayed to Mar 92

1991

- AQCESS required upgrade or replacement. Software Version 4.1 would replace AQCESS (AQCESS-R Program)
- IOC-R Program canceled
- Disk space and performance become a problem. GAO stated the two issues are related and demand CHCS be able to archive (and retrieve) data off the system
- For Mar 92 Milestone III decision, MAISRC and GAO agreed on the following
  - Milestone III was split into IIIA (Outpatient functions) and IIIB (Inpatient Order Entry (IPOE))
  - Early Operational Assessment of Version 4.1 (look in the SAIC lab only)
    - AQCESS-R software
    - Archive/Retrieve capability
  - Software Version 4.0 at six of the beta test sites
  - Charleston Performance Report (Charleston was the first site to upgrade the MicroVAX 4200s to VAX 6400s)

1992

- PAS becomes critical at some of the IOC sites
- Since PAS is the most stable CHCS software and most likely the first module to be "certified", the MAISRC approved deployment of PAS only at the following AF PAS Certification Sites
  - Travis
  - Scott
  - Offutt
- IOCs become more critical
- MAISRC approved CHCS 19 May 92 "pending OT&E report". OT&E report did not go out until 15 Nov 92. Congress had 60 days to approve. If no action was taken, approval would be automatic

1993

CHCS passed Milestone IIIA 15 Jan 93

In Feb 1993, CHCS underwent a MAISRC IPR with the following directions

- IOCs must be replaced by Sep 94 (For the AF, this was to be accomplished by MEDSITE)
- TMPS would be replaced by Sep 94
  - TMPS was to be replaced immediately using CHCS on a single personal computer (PC) running under the DOS operating system. The system became known as PC-SAPH (Stand Alone Pharmacy)
- AQCESS must be replaced by Sep 95
  - This would be available later in 1993 using multiple PCs running under the UNIX operating system. The system became know as PC-CHCS.
- Managed Care Program (MCP) software must be deployed to the right base at the right time

In Aug 93, TMPS-R and AQCESS-R programs were combined into a single program

1994

In Jan 94, PC-CHCS was deployed to 6 alpha sites, 2 from each service

In Jun 94, PC-CHCS was approved by OT&E

4.3.5 MEDSITE

MEDSITE is an acronym for **MED**ical **S**ystems **I**mplementation and **T**raining. Approved by the Air Force Surgeon General in March 1993, MEDSITE's mission was to deploy CHCS to those Medical Treatment Facilities (MTFs) which had existing Initial Operating Capability (IOC) systems (TRIPHARM, TRIRAD, TRILAB, TRIPAS).

When PC-CHCS was approved for accelerated deployment to all other MTFs, Lt Gen Sloan approved a ramp up of MEDSITE and Standard Systems Center (SSC/SBM) to deploy CHCS Patient Appointing and Scheduling (PAS), Patient Administration (PAD), Managed Care Program (MCP) and Pharmacy (PHR).

SSC/SBM hired 4 of 38 needed term employees to deploy PC-CHCS to 29 MTFs in eastern CONUS/USAFE. MEDSITE hired 54 term employees to deploy PC-CHCS to 30 MTFs in western CONUS and PACAF, to manage the PC-CHCS project and to operate an AF CHCS Support Center.

MEDSITE currently maintains a software team which develops interfaces between CHCS and other various medical information systems, as well as report generators and other specific modules. Some interfaces are developed as a final deployable product while others are developed as a prototype effort to provide a proof of concept and provide a better understanding of the level of effort required to develop a fully functional interface for the system in question. The team also develops hard coded report modules in situations where using a generic ad hoc report generating tool is ill suited to the task either because of complexity or performance.

Current MEDSITE Team Members:

Maj. Ray Bender, Director

E-mail: ray.bender@xmail.ha.osd.mil

Mr. Gregory Zymbaluk, Computer Sciences Corporation, Programmer

E-mail: gregory.zymbaluk@xmail.ha.osd.mil

Mr. Eugene Gonzales, Computer Sciences Corporation, Programmer

E-mail: eugene.gonzales@xmail.ha.osd.mil

Team Member Emeritus:

Capt. Loretta Hagen, Chief (former)

MEDSITE maintains WWW pages at URL:

http://bender.brooks.af.mil/

This server has descriptions and M source code of the public domain software that is currently available from MEDSITE, and to be developed in the future. Some of the interfaces that have been developed are:

Telephone Refill
TransLux DataWall
Pyxis Medstation ADT
Provider Workstation Results Retrieval
TRAC2ES Patient Movement Request
MICROMEDEX

Some of the report generators that have been developed are:

Pharmacy Cost Reports
Medicare Eligible Cost Reports

MEDSITE's deployable systems have been installed at:

Guantanamo Bay, Cuba - (Operation Sea Signal)
Zagreb, Croatia - (UN Protective Forces)

MEDSITE's required future work includes:

Deploy CHCS LAB to all AF MTFs by Dec 95
Deploy CHCS RAD and Order Entry by Dec 96
Support training for software upgrades for existing MTFs

Future work for MEDSITE may also involve becoming or forming an executive agent for the Consolidated Medical Systems Support Center (COMSSC) .

4.3.6 Case Study Of Remote USAFB CHCS Site: Guantanamo Bay, Cuba

This section will provide excerpts from a May, 1995 USAF "After Action Report" [19] which describes the humanitarian-mission/medical-effort carried out recently in Cuba, code-named "Operation Sea Signal". These excerpts will serve to explain how CHCS was deployed in a mobile context and what the various camp implementation issues were for that context.

4.3.6.1 Excerpts From Executive Summary of Operation Sea Signal

As part of Operation Sea Signal humanitarian mission, the Joint Task Force (JTF) 160 Surgeon General (SG) was responsible for the care and support of the 21,000 Cuban migrants and approximately 500 Haitian migrants housed at the Guantanamo (GTMO) Bay encampments. Specifically, the medical care for the migrants was provided by the 6th and 59th Air Transportable Hospitals (ATHs). There was a wide range of medical services provided by these ATHs.

There was little automation deployed with the 6th and 59th ATHs. The requirements for basic medical automation in an ATH are the same as any fixed medical treatment facility - pharmacy, lab, radiology, results retrieval, patient registration and electronic mail. The purpose of this deployment was to support these basic requirements as well as validate new requirements specific to a deployed unit.

The major deficit in GTMO and within the ATHs was the lack of any type of computer/communications infrastructure. Naval Base (NAVBAS) GTMO had a wide area network (WAN) but the ATHs were not located in any area easily linked to this WAN. Secondly, the telephone infrastructure was saturated. Within the ATH, administrative duties were accomplished through the use of personal laptop computers that people had brought from home stations. After 11 months of use, they were beginning to break down and there was much concern about replacements. Telephones were limited to "field" phones linked by 4-wire tactical lines. At the 6th, there was not any link to electronic mail within the ATH or a link into the Internet. At the 59th, located across the street from the Camp Bulkeley J-6 (USMC), they had found a means to link up to the J-6 Banyan Vines server through tactical wire to provide them with access to e-mail at home. The 59th had no connectivity within the ATH. The pharmacy at the 6th ATH had brought Z-248 Tri-Service Micro Pharmacy System (TMPS) but they continued to have breakdowns. The 59th ATH did not have TMPS but did have the capability to use a personal computer (Z-248) with Pharmacy Label Producing Software (PHLAPS) for printing prepack labels.

MEDSITE's deployment of the Composite Health Care System (CHCS) to GTMO Bay was prompted by a request from the pharmacist assigned to the 6th ATH. After receiving approval from the ATH Commander, the JTF/SG, USACOM/SG, and the AF/SG, MEDSITE put together an DEC Alpha AXP capable of supporting a minimum of 25 concurrent users and enough disk storage for one year of on-line data. The system was installed in the 6th ATH with plans to tie all medical activities together.

4.3.6.2 Deployment Strategy/System Configuration

MEDSITE deployed a DEC Alpha (AXP) 3000/300 with CHCS Version 4.2/MU2 software. Peripheral hardware included DEC VT 320s, LA75 text printers, and Data South 300 XL label printers. Connectivity was via Local Area Transport (LAT) using DECServer 300s. Connectivity to outside locations was accomplished by connecting line drivers and bridges/routers through phone or tactical lines. Other specifics for hardware are listed below:

Product or Function	**Item**
CPU	DEC Alpha AXP 3000/300 RISC based 125mHz
DEC StorageWorks	1.5 GB DAT backup storage tape 1.2 GB Disk Drive CD-ROM
Memory	64 Megabytes RAM
Disk Storage	20 Gigabytes (10 - 2.01GB disk drives)

Backup	Disk to Tape Disk to Disk
Operating System Software	OpenVMS Version 6.1 DSM Version 6.3d CHCS Version 4.2/MU2
Other	TGV Multinet PWS/TRAC2ES Interface software

4.3.6.3 Communications

The AXP only has a 10BaseT connector and the DECServer only has a 10Base2 connector. A Boca Hub with a 10BaseT and 10Base2 was used to connect the AXP with the DECServer 300s. Running 6-wire unshielded twisted pair within the 6th ATH, VTs and printers were connected to DECServer 300s.

A link between 59th to JTFJ6 already existed. The Camp Bulkeley J6 (USMC) had connectivity between their Banyan Vines server and the JTFJ6 Banyan Vines server in the Pink Palace. A tactical line from the 59th ATH had been run across the street to the Camp Bulkeley J6. Since the JTFJ6 at the Pink Palace was linked to the Internet, both the 59th and the Bulkeley J6 were linked to the internet. The goal was to link the 6th ATH into the same Banyan Vines server at the Pink Palace so we could access either the internet or the 59th ATH. If the NAVHOS[20] GTMO had access to the internet then we could theoretically access them once we were on the internet.

Linking the 6th ATH to the JTFJ6 Banyan Server. The Navy Communication Detachment (NAVCOMMDET) at GTMO provided two cable pair that we used to attach two AT&T 3510 line drivers and two DECrouter 90T1 bridge/routers. One end was attached to CHCS via the Boca Hub while the other router and modem were attached to the JTFJ6 Banyan Vine server. We had continuous problems with keeping the link up between the two modems. When the link was up we were able to telnet to the Banyan router and get to the internet.

Linking the 6th ATH to Camp Clinics (first is Lima/Mike camp) and the 59th to Camp Clinics (first is Echo/Foxtrot camp). Although two Codex 3500 line drivers were taken to connect Lima/Mike with the 6th, they were never tested because the lack of cable pair or commercial phone lines going to these clinics. A link in the future would require some type of wireless technology. LCDR Tillery and LT Welch visited from Naval Medical Information Management Center (NMIMC), they had discussed the installation of a cell on one of the hills and using cellular phones/modems to hook up the ATHs with their outlying clinics.

Connect to NAVHOS GTMO. The 6th ATH and the NAVHOS were both able to provide a single phone number that allowed modem access between the two facilities. Although not very fast we were able to link the NAVHOS Lab to CHCS using a pair of 2400 baud modems. Although we had taken 9600 baud modems we were unable to get the DECServer 300 to talk to them. Between the Pink Palace, Deer Point, and NAVHOS there is a clear line of site which is less than 4 miles total distance. Wireless technology could be used in the future.

4.3.6.4 CHCS Advantages

Results that were being recorded on separate log sheets and log books can now be found and printe a collated report in less than five minutes compared to 20 minutes or more without CHCS. All specimens entered into CHCS were immediately accompanied by an audit trail providing positive specimen tracking. I addition special reports such as the Pending Lists, Overdue Procedure Reports, and Uncertified Results Report provided lab management an easy way to monitor the status of any test and take corrective actions tc ensure results are returned in a expeditious manner not lost in a mountain of loose papers. Results were

accessed from anywhere in the ATH there is a terminal, not just at the laboratory. This reduced the amount of time wasted walking to the lab to research what happened to a result. Electronic mail was used to pass information on protocol changes to different shifts, easing dissemination of critical operating policies.

4.3.6.5 CHCS In Emergency Unit

A CHCS terminal was placed in the Triage area (open tent adjacent to ER). This allowed the ER tech to triage the patient, take vitals, and print the 558 to the main ER. Changes were made to CHCS to allow the triage technician to enter directly into CHCS the patient's vital signs and to add comments he wanted to pass on to the ER. Once complete the 558 was printed on the ER printer. The bottom of the 558 was also changed to allow the understanding statement to print in Creole or Spanish.

An Information Desk Display was added to the Emergency Room main menu to allow for easy and fast look up of admitted patients.

4.3.6.6 DMPITS Database Conversion

Patient tracking was a problem at the ATHs. Some sections were using the US Atlantic Command (USACOM) developed Defense Mass Population Identification and Tracking System (DMPITS). There were multiple problems identified with DMPITS: (1) lack of confidence in the data accuracy because registration information was not verified at the time enrollment; (2) lack of devices in each section (many of the devices were broken and did not work); and (3) the DMPITS was not on a network, leaving each section to build their database. DMPITS was updated manually once per week based on data provided to a central location. CHCS would provide a means for accurately tracking patients through the ATH as all would use one central patient database.

The DMPITS office provided a DOS "flat file" containing the Name, DMPITS Number, Date-of-birth, Sex, Camp, Tent, and Bed. This file was transferred to the Alpha using a laptop computer. A conversion program was written in MUMPS to read the file and insert the data elements into the CHCS database providing pre-registration for all migrants.

4.3.6.7 After Action Conclusions

The DEC Alpha proved to be the ideal platform for simplified system management required for a deployed system. A single CPU system eliminated the problems with database synchronization and greatly simplified back-up procedures. The performance was excellent and better than expected. Any deployable system should be fully scaleable if future upgrades become necessary. Finally, the OpenVMS operating system was very robust and tolerant of unexpected "crashes" that are often a fact of life when operating in a tent environment operating off generator power. All the ATH components (CPU, DECServers, VT 320s, LA 75s) were configured at MEDSITE and tested for compatibility and reliability prior to deployment. This part of the deployment went smoothly and as predicted. However, the remote communication solutions between all the medical facilities at GTMO were not tested because the availability of the type of physical wire was unknown. In the future one needs to know the location of the nearest Wide Area Network (WAN) connection and the locations of any remote sites that will be connected to the CPU. The distances from the CPU to these locations must be known as this will drive the communication solutions. Based on this information, the team should deploy with one or more solutions for each type of remote connections. The deployment to GTMO was very successful. The ability to get daily A&D reports; the ability to track the pregnant migrant women by camp, DMPITS number, and EDC; the ability to better track and monitor drug distribution, whether by prescription or by bulk issue; the ability to quickly send panic lab values directly to the clinic or ER; and the ability to register and track patients all improved the efficiency and quality of care

being given by the 6th ATH. From this test deployment, many lessons were learned regarding the flexibility of CHCS and the flexibility required to support both humanitarian as well as wartime missions. These lessons will be used to better train our people for future deployments.

4.4 Civilian HIS Vendors (HBOC, SMS, MEDITECH, KEAN, CERNER)

HIS Vendor/Rank	No. of Installed Units	Price Range Per Install
1) HBO & C	2,600[21]	$700 K to $1 Million[22]
2) SMS	-	-
3) MEDITECH	700+	-
4) KEANE	945	-
5) CERNER	-	-

Of the above five, Kensal Corporation has received literature from HBO&C, SMS, MEDITECH, and KEAN. A brief overview of these firms is presented next.

4.4.1 HBO & Company (HBOC)

HBOC
301 Perimeter Center North
Atlanta, Georgia 30346
Phone (404) 393-6000
FAX (404) 393-6092

Literature Received:
- Corporate Overview . . . . No
- List of HIS Modules . . . . Yes
- List of Services . . . . Yes, Network solutions
- Complete description of each module . . . . No
- Innovative Peripherals . . . . No
- Third-party reviews . . . . No

4.4.1.1 Overview

HBOC is a healthcare information solutions company that provides information systems and technology for the health enterprise--hospitals, integrated delivery networks and managed care organizations. HBOC claims to offer products and services to meet virtually every need the enterprise has for information, whether patient care, clinical, financial or strategic management.

HBOC markets local, metropolitan and wide area network services; HBOC's client/server-based Pathways 2000 suite of applications provide key elements for integrating and uniting providers across the continuum of care and establish the infrastructure necessary for a lifelong patient record. Its hospital-based STAR, Series and HealthQuest transaction systems and TRENDSTAR decision support system--along with the clinician-focused Pathways 2000 products--help improve the delivery of health services to an entire community. The Pathways 2000 resource scheduling and managed care solutions and QUANTUM enterprise information system support the critical business functions necessary to manage today's emerging health networks. In addition, agreements and alliances with business partners allow HBOC to offer a broad variety of complimentary applications and technology, such as physician practice management system.

HBOC wraps these products with such services as planning, implementation and support, plus education and training. HBOC also offers a range of outsourcing services that includes strategic information systems planning, data center operations, receivables management, business office administration and major system conversions.

4.4.1.2 HBOC's Network Solutions

HBOC has noted that healthcare is drastically changing in the way it conducts its business. Fee-for-service is giving way to managed care and competition. Stand-alone hospitals are being incorporated into health enterprises. Wellness is being measured by outcomes rather than amounts of care and patient chart size by transmission time rather than page count.

With such change, HBOC is attempting to address the following information requirement issues: 1) How do organizations share information among the many new players in a managed care environment? 2) How do they provide meaningful information for universal access throughout the facility? 3) How do separate organizations exchange the information required for a true computer-based patient record? 4) And how does any healthcare entity avoid system obsolescence in a technological environment that's advancing exponentially? 5) How do organizations build an information infrastructure to support a rapidly and constantly changing environment?

HBOC has formed "HBO & Company's Connect Technology Group" (CTG) to address the aforementioned issues based upon the conviction that retrieving, integrating and presenting information from disparate sources to an expanding variety of users will become critical in the new world of healthcare--and that networks will make these tasks possible. CTG has more than 20 years of healthcare industry knowledge, more than 100 healthcare network installations, advanced networking expertise and "proven experience" in providing information.

<u>4.4.1.2.1 HBOC's Method and Approach to Network Solutions</u>

HBO&C claims that is the only major HIS vendor able to provide "one-stop shopping" for hardware, software, information networks and maintenance. CTG offers complete network installation, including a variety of telecommunications services:

- **Requirements Definition:** HBOC performs a comprehensive analysis of the hospital's short-term and long-term communications needs.

- **Functional Design:** Based on information gathered during requirements definition, HBOC recommends LAN media and hardware and software configurations.

- **Final Design, Installation Planning and Project Planning:** HBOC completes the preliminary design fro the cabling system and develops and installation timetable and detailed installation plan.

- **Procurement and Materials Management:** HBOC orders LAN hardware, software and cabling components and carefully tracks these orders to ensure timely delivery.

- **Project Management and Installation:** HBOC monitors and periodically reports on all installation work to ensure timely and proper installation and configuration.

- **Testing and Quality Assurance:** The CTG project management and installation team verifies all aspects of the LAN implementation including user

training and satisfaction.

- **Post-Installation Operation Management:** Customers may contract for additional consultation, support, management or disaster recovery planning services.

HBOC's health enterprise networking services ranges from LAN to MAN to WAN, with the WAN applications still under development:

- **LAN (Local Area Network)**
  - Patient-Focused Stations
  - Outpatient Surgery
  - Patient Accounting
  - Materials Management
  - Medical Records
  - Physician Offices
  - Radiology
  - Pharmacy
  - Laboratory
  - Emergency Room
  - Point of Care
  - Business Office
  - Executive Decision-Makers
  - Wellness Centers
  - Technology Management Systems
  - Community Network Access

- **MAN (Metropolitan Area Network)**
  - Payers
  - PPOs, HMOs, PHOs
  - Alliances, AHPs
  - Employers
  - Physician Offices
  - Home Health
  - Consultants
  - Banks
  - Local Governments
  - Skilled Nursing Facilities
  - Referrals
  - Medical Literature Databases
  - National Network Access

- **WAN (Wide Area Network)**
  - Clearinghouse
  - Federal Government
  - Employers
  - State Governments
  - Payers
  - Clinical Databases
  - Banks
  - Financial Databases
  - National Diagnostic Centers
  - Computer-Based Patient Record

4.4.1.3 HBOC HIS Modules

HBOC markets two HIS systems under the titles STAR Solutions and Series Solutions with apparently few differences in the literature other than different platform implementation options and minor variance in offered module types. Since the STAR system is the newer, an overview of its major modules only is presented below.

The STAR Modules share a single logical database with immediate access to authorized users from any workstation on the network. Comprehensive reporting tools are provide by the STAR KB_SQL report writer.

<u>4.4.1.3.1 STAR Patient Care</u>

This is the patient-centric hub of the HIS network. STAR Patient Care is where vital patient information is entered, maintained, tracked and disseminated throughout all departments.

Application Software:

- o Patient Processing
- o Patient & Resource Scheduling
- o Nursing
- o Order Management
- o Scheduling Departmental Profiling
- o Physician View

<u>4.4.1.3.2 STAR Radiology</u>

STAR provides a computerized clinical and administrative radiology information system that serves the areas of diagnostic radiology, nuclear medicine, ultrasound, magnetic resonance imaging, special procedures, computed tomography, mammography and radiation therapy.

Application Software:

- o Patient & Resource Scheduling
- o Order Management
- o Exam Resulting/Reporting
- o Film/File Room Management
- o Activity Tracking
- o Report Review Process
- o Administrative/Management Reports
- o Historical Patient Index
- o Quality Assurance

<u>4.4.1.3.3 Pharmacy</u>

A pharmacy system that addresses both inpatient and ambulatory areas. HBOC claims that it opens new avenues of communication, enhances teamwork and streamlines operations.

Application Software:

- o Profile Management
- o Order Entry
- o Dispensing Management
- o Clinical Services
- o Inventory & Purchasing Management
- o Productivity & Management
- o Reporting

- Formulary Maintenance

4.4.1.3.4 Laboratory

The goal of this system is to ensure quality of outcome through far-reaching communication, data integrity and management control. Extensive quality control features help ensure the reliability of test results and the appropriateness of care delivered.

Application Software:

- Order Management
- Test Processing
- Patient Inquiry
- Patient Result Reports
- Quality Control
- Administrative/Management Reports
- Surgical Pathology
- Advanced Microbiology
- Advanced Blood Bank
- Contract Management

4.4.1.3.5 Financials

An executive management tools and general financial applications module.

Application Software:

- Patient Guarantor Accounting (Data Collection, Billing, Insurance Follow-up/Collections, Account Management, Third-Party Logs)
- General Ledger
- Accounts Payable
- Materials Management
- Human Resource Management
- Medical Records

4.4.1.3.6 TRENDSTAR

A decision support system which offers "point and click" access to information, analytical functions, reporting and presentation tools.

Trendstar complements HBOC's STAR and HealthQuest financial and clinical products by providing managed care contracting and monitoring, quality and case management, budgeting, forecasting and strategic planning solutions to support enterprise-wide decision-making.

Application Software:

- Hospital Systems Library
- Clinical Cost Accounting
- Contract Payment Advisor
- Management Cost Accounting
- Marketing Systems Library
- Resource Utilization Analysts
- EpiTREND Reporting System
- TRENDPATH

4.4.1.3.7 QUANTUM

An executive information system (EIS) that "empowers executives by pulling together up-to-the-minute information from all the key areas of the healthcare enterprise." This digital entry allows a user to monitor operating targets, critical success factors, market trends or daily events.

4.4.1.3.8 Hardware and Operating Systems

STAR Solutions:
- o Hewlett-Packard UNIX
- o Data General UNIX and AOS/VS II
- o Digital Equipment Corporation's VMS
- o IBM RISC System/6000 AIX

SERIES Solutions:
- o IBM AS/4000 with OS/400
- o RISC System/6000 with AIX

4.4.2 SMS (Shared Medical Systems Corporation)

SMS
51 Valley Stream Parkway
Malvern, PA 19355-1406
Phone: (610) 219-6300
FAX: (610) 219-3124

Literature Received:

Corporate Overview	No
List of HIS Modules	Yes
List of Services	No
Complete description of each module	No
Innovative Peripherals	No
Third-party reviews	No

4.4.2.1 Overview

Unfortunately, SMS only sent to Kensal Corporation literature describing their SMS OPENLab, a client/server laboratory information system (LIS). Since an LIS is a subset of an HIS, a brief overview of SMS and their the OPENLab system is presented.

4.4.2.2 Voice Recognition And Multimedia

SMS OpenLab supports voice recognition and multimedia technology. Examples of multimedia features include on-line Help, CD-ROM reference manuals, scanned images for user-tailored Help files, full motion video and potential links to hospital satellite connections for remote training sessions, documentaries and network-wide continuing education and training opportunities.

4.4.2.3 Encoding Enterprise Rules

OPENLab automates administrative tasks and exception alerts while eliminating redundancy. Operational and clinical rules capabilities are embedded into OPENLab. For example, users can set up results reporting based on criteria such as location, choice of print media, day of the week or time, to ensure that results are delivered to the appropriate clinicians immediately and in the format they desire.

4.4.2.4 Open Systems Approach

OPENLab is based on an open system approach, enabling users to choose the technology and operating system that best fits their needs. Users may use off-the-shelf software such as report writers, spreadsheets, databases and word processing applications. Optionally, an OPENLab system includes an HL7/ASTM compliant interface engine to optimize network and system communications. Further, full support of point-of-care testing devices, faxes, printers and pagers in physician offices is provided.

4.4.2.5 Ad-Hoc Reports

Users can define ad-hoc report formats which integrate data, text, and graphical representation of results. The need for ad-hoc reporting was underscored by SMS since the laboratory marketplace is constantly changing. Microsoft Access was cited as an example of a "canned-package" that combines the power of a relational database with an easy-to-use graphical report writer.

4.4.2.6 Augmentable On-Line Help

Context sensitive on-line help can be augmented to include standard operating procedures, scanned images, CD-ROM reference manuals, and multi-media capabilities with full motion video. SMS claims that "any number of third party packages" may be used to include text and graphics into the Help feature.

4.4.2.7 On-Line Screen Editing

Rather than contracting SMS to alter screens every time a change is needed, an on-line screen editor is available which enables a user to tailor screens to meet individual specifications, improve system flow, and user productivity. The reconfigurable features are: the prompt text, tabbing sequence between fields, and the layout of fields over one or more screens. Changes can be executed throughout the system without bring the OPENLab system down.

4.4.2.8 Flexible Human-Interface

OPENLab is GUI-based, multitasking compliant, and has user-definable security levels. In addition to support of mice, track balls, keyboards, and "hot keys"--light pens and touch-screen data entry options are available. A common user-interface model may be applied over the client/server technology; however, entity-specific (client) tailoring is allowed for improved end-user throughput.

4.4.2.9 Platform and Network Hardware

PC, IBM RISC System/6000, Digital VAX/VMS, Alpha, HP, Ethernet LAN.

4.5 MEDITECH (Medical Information Technology, Inc.)

MEDITECH
MEDITECH Circle
Westwood, Massachusetts 02090
Phone: (617) 821-3000
FAX: (617) 329-9977

Literature Received:

Corporate Overview	No
List of HIS Modules	Yes
List of Services	No
Complete description of each module	Yes
Innovative Peripherals	Yes, Handheld Computer
Third-party reviews	Yes

4.5.1 Overview

Meditech is a software and service company who develops, installs, and supports information systems for health care organizations of all sizes. Meditech emphasizes their technical innovation such as the new Handheld Point of Care Computer[23], and their "enterprise-wide computerized patient records." Meditech offers perpetual license agreements, periodic enhancements, ongoing education, and free system upgrades so customers can migrate to new technologies as they develop.

Meditech has 700+ installations (as of 1994) worldwide, with a majority of the customers located in the United States, Canada, and the United Kingdom. Meditech has averaged more than 80 new customers annually during the past five years.

Meditech emphasizes a flexible, integrated approach to information systems which provide patient-based information, open systems connectivity, and easy to use decision support tools necessary for today's community health care enterprises.

Clients may build information networks comprised entirely of Meditech applications or combine Meditech's modules with other vendor's products in open networks.

Meditech boasts a design principal which mandates that information systems be easy to use. One example they point to is their PCI (Patient Care Inquiry) product, used by many physicians, and can "literally be learned in five minutes."

4.5.2 Meditech's Integrated Health Care Information System (HCIS) Products

Product	**No. of Customers Licensed per Product as of 5/1/95**	**Introduction Date**
Admissions	507	1971
Anatomical Pathology	386	1980
Blood Bank	365	1981
Case Mix Mgmt	471	1984
Clinicians' On-Line Reference	23	1992
Community-Wide Scheduling	257	1995
Departmental	347	1991
Laboratory	548	1969
Medical Records	505	1972
Microbiology	518	1970
Nursing	416	1984
Order Entry	474	1990
Patient Care Inquiry	400	1988
Pharmacy	455	1975
Radiology	365	1980

Accounts Payable	404	1978
Billing/Accts Receivable	419	1977
Budgeting & Forecasting	18	1994
Cost Accounting	132	1985
Executive Support System	207	1991
Fixed Assets Accounting	266	1981
General Ledger	406	1978
Office Automation	313	1986
Materials Management	350	1980
Payroll/Personnel	374	1982
Optical Disk Archiving	109	1993
PC Workstation Software	293	1993

4.6 KEANE, Inc.

Keane, Inc.
Healthcare Services Division
290 Broadhollow Road
Melville, NY 11747
Phone: (516) 351-7000
FAX: (516) 351-7115

Literature Received:

Corporate Overview	Yes
List of HIS Modules	Yes
List of Services	No
Complete description of each module	Yes
Innovative Peripherals	No
Third-party reviews	No

4.6.1 Overview

John F. Keane founded the company in 1965 as a sole proprietorship and in 1967 incorporated the company in Massachusetts. Keane has since grown into a $350 million company with over 4,000 business and technical professionals. Headquartered in Boston, Massachusetts, Keane provides services across a network of over 40 branch offices throughout the United States and Canada.

Keane's initial corporate objectives were to assist companies in the design, development and implementation of computer systems and provide project management services to Fortune 1000 firms. Keane is now also well known for its project management methodology, Productivity Management and for the ability to complete even the most complex projects on time and within budget.

Keane's mission is to help organizations leverage their software assets and resources to achieve their business objectives. Keane strives to build long-term, mutually beneficial relationships with its client companies by effectively addressing their software development needs. Keane's success in meeting their needs has enabled the company to derive more than 90% of its annual revenue from existing clients. It has also resulted in Keane being recognized as one of the best managed small companies in the United States by publications such as Businessweek, Forbes, Financial World and Investors Business Daily.

Keane has two operating divisions: the Information Services Division (ISD) and the Healthcare Services Division (HSD). ISD provides custom applications software for corporations with large and recurring software development needs. Application software development includes systems planning, analysis, design, and maintenance. ISD also provides project management and help desk out-sourcing for clients.

Keane's Healthcare Services Division develops and supports a full line of UNIX-based "open" hospital applications including Patient Management, Financial Management, Patient Care and Clinical Systems. The Leadership Plus Series, a PC-based Long Term Care solution is Keane's offering for the long-term care market.

Headquartered in Melville, New York, the Healthcare Services Division has branch offices in Hunt Valley, Maryland, and Los Angeles, California."

4.6.2 Division Overview

In 1984, Keane made its software available as a turnkey package. This full line of modular, yet integrated, software applications solidified Keane's reputation in the marketplace. In April of 1992, Keane acquired Ferranti Healthcare Systems Corporation, a software provider for acute-care hospitals and long-term care facilities. This acquisition expanded Keane's geographical presence in the acute and rehabilitation hospital market and added approximately 300 long-term care clients with 700 facilities located across the United States. In August of 1993, Keane acquired the software and selected assets of Professional Healthcare Systems, Inc. headquarted in Los Angeles, California. This acquisition brought to Keane a prestigious client base, including large teaching hospitals and several large healthcare chains. In April of 1995, Keane acquired the Infostat division of Community Healthcare Computing, positioning Keane among the top healthcare information systems vendors in the country and increasing Keane's install base to over 230 hospitals.

Keane currently markets and supports a full line of information systems for the healthcare environment:

Threshold: a comprehensive hospital information system, uses open system computing technologies that combine RISC-based hardware, the UNIX operating system, a fourth generation programming language, and a relational database management system.

Patcom: a proven, highly rated Patient Management System designed for large teaching hospital and multi-entity facilities.

Leadership Plus: the premier financial and resident care system for long-term care facilities.

In addition to application software, Keane offers support services that include new enhancements to meet changing regulatory requirements, hot-line, and remote diagnostics. Keane continues to offer both facilities management and transition management that provide either long-term or short-term on-site system support, training and management.

4.6.3 Threshold Hospital Information System

The following from Keane document no. 08194T:

Patient Management System
Patient Accounting: Inpatient ADT/Census
Outpatient Registration

Billing/Accounts Receivable/Collections

Medical Records: Central Index
Abstracting/Reporting/DRG Grouping
Chart Deficiency
Chart Tracking

Financial Management Systems
Accounts Payable
General Ledger/Budgeting
Payroll/Personnel
Materials Management

Clinical Systems
Order Communications
Laboratory
Pharmacy
Radiology

Executive Management Support
Managed Care
Executive Information System
Employee Scheduling
Document Imaging

Supplemental Systems
Quality Management
Infection Control
Utilization Review
Medical Staff Administration
Home Health Information

4.7 References

1. *Decision support systems* (DSS) are interactive, computer-based information systems that use decision models and specialized databases to assist the decision-making processes of managerial end users. A DSS provides ad-hoc report generation, analytical modeling, data retrieval, and information presentation capabilities. Thus DSS's differ from the pre-specified responses generated by *information reporting systems* (IRS) which provide information products that support data-to-day decision-making. *Executive information systems* (EIS) are tailored to the strategic information needs of top or middle management. EIS provides the current status and projected trends for key factors selected by top executives.

2. This eliminates communication traffic problems between nodes. Data being transmitted is first stored and waits until bandwidth is available for transmission. This does two things, 1) frees up the end-user's terminal to work on other things while the data is queued and, 2) ensures fault-tolerant delivery of data incase of temporary disconection during transmission--data can be resent.

3. Medical Reords Institue Web Pages (http://www.medrecinst.com/)

4. Many hospitals still keep much of the patient record on paper in a folder labeled with the patient's unique HIS index number.

5. Medical Records Institute, 567 Walnut Street, P.O. Box 289, Newton, MA 02160 USA; Phone: (617) 964-3923

6. See Appendix A, Networking And Standards, paragraph A.2 and the ATM Forum, at WWW URL http://www.atmforum.com

7. The following is from the Medical Records Institue, "Standards in Health Care Informatics" web page (http://www.medrecinst.com/).

8. Medical Records Institue, 567 Walnut Street, P.O. Box 289, Newton, MA 02160 USA, (617) 964-3923

9. This directory costs $42.50

10. Much of the following comes directly from a Los Alamos National Laboratory web page (http://www.acl.lanl.gov:80/sunrise/).

11. *Message transformation* is translating and mapping data to other formats, splitting (sending to multiple destinations) or compounding (receiving from multiple sources) messages.

12. According to a GartnerGroup Research Note (April 13, 1995; HCV), larger hospitals choose a "best-of-breed" approach to selecting applications (i.e., the best lab system, the best pharmacy system) with little concern for each application's overall architectural fit.

13. EDI - Electronic Data Interchange

14. ASTM - American Society for Testing and Materials

15. SAIC Headquarters, 10260 Campus Point Drive, San Diego, CA 92121, (619) 546-6000

16. J.R.Beyster is currently SAIC's Cheif Executive Officer

17. Statement from SAIC 1995 Annual Report, Information Technology, located at WWW URL: **http://139.121.25.30/**

18. The following information is from MEDSITE URL: **http://bender.brooks.af.mil/www/chcs.html**

19. After Action Report by Lt. Col. Lynn Ray, available through MEDSITE WWW URL: **http://bender.brooks.af.mil/**

20. NAVHOS - Naval Hospital

21. According to Ms. Monica Brown, HBOC Investor Relations, (404) 668-5926

22. Cost dependant on what client buys--typical HIS is 4 to 5 modules.

23. See section 1.5 Computer-based Point of Care

APPENDIX A
NETWORKING AND STANDARDS

Many HIS systems connect various computer systems together within the hospital and these systems branch out to terminals for end-users. Such networks in the local environment are known as Local Area Networks. However, linkages to the HIS are not limited to within the LAN. External forces are pushing the internetworking boundaries of the HIS.

It has become difficult for hospitals to stand alone. Health care reform is driving a new health care model-- a hospital today is just one stop along an entire continuum of care that can include other providers such as physician offices, home health agencies, PPOs (Preferred Provider Organizations) and HMO (Health Maintenance Organizations). Local medical centers are joining together to become regional systems who are themselves tapping into national data resources to improve decision making and compare thier performance to others nationwide.

Organizations must share caregiver information as patients move along the continuum. They must establish two-way links with national and regional data-bases to report and use ubiquitous data critical to ascertaining risk and providing cost-effective care. As a result, today's health delivery model is three-tiered, its orientation radiating outward from the local, stand-alone organization to the regional, community-based system to the national governing organization.

The following section examines some of the network technology being used to establish these local area networks (LANs), metropolitan area networks (MANs), and wide area networks (WANs).

A.1 Ethernet, A Local Area Network Technology

Ethernet[1] is a local area network (LAN) technology that transmits information between computers at speeds of 10 and 100 million bits per second (Mbps). A LAN is defined as a privately owned data communications system that usually covers a relatively limited territory, hence the term "local area."

Currently the most widely used version of Ethernet technology is the 10-Mbps twisted-pair variety. The 10-Mbps Ethernet varieties include the original thick coaxial system, as well as thin coaxial, twisted-pair, and fiber optic systems. The most recent Ethernet standard is the 100-Mbps system which is based on twisted-pair and fiber optic media.

A.1.1 Ethernet is a Popular, Vendor-Neutral Network Technology

There are several LAN technologies in use today, but Ethernet is by far the most popular. Networking vendors estimate that as of 1994 there were nearly 40 million Ethernet nodes installed worldwide. The widespread popularity of Ethernet ensures that there is a large market for Ethernet equipment, which helps keep the technology competitively priced.

From the time of the first Ethernet standard the specifications and the rights to build Ethernet technology have been easily available to anyone. This openness resulted in a large Ethernet market, and is another reason Ethernet is so widely implemented in the computer industry today.

The vast majority of computer vendors today provide equipment with 10-Mbps Ethernet attachments, making it possible to link all manner of computers with an Ethernet LAN. As the 100-Mbps standard becomes more widely adopted you can expect to see computers equipped with Ethernet interfaces that operate at both 10-Mbps and 100-Mbps.

The ability to link a wide range of computers using a vendor-neutral network technology is an essential feature. Most LANs today support a wide variety of computers purchased from different vendors and require a high degree of network interoperability, which Ethernet provides.

A.1.2 Development of Ethernet Standards

The specifications for Ethernet were first published in 1980 by a multi-vendor consortium that created the DEC-Intel-Xerox (DIX) standard. Ethernet technology was then adopted for standardization by the 802 LAN committee of the Institute of Electrical and Electronics Engineers (IEEE).

The IEEE standard was first published in 1985, and its formal title is "IEEE 802.3 Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications." This standard provides an "Ethernet like" system based on the original DIX Ethernet technology. All Ethernet equipment since 1985 is built according to the IEEE 802.3 standard, which is pronounced "eight oh two dot three."

To be absolutely accurate, then, we should refer to Ethernet equipment as "IEEE 802.3 CSMA/CD" technology. However, most of the world still knows it by the original name of Ethernet, and that's what we'll call it as well.

The 802.3 standard is periodically updated to include new technology. Since 1985 the standard has grown to include new media systems for 10-Mbps Ethernet (e.g. twisted-pair media), as well as the latest set of specifications for 100-Mbps Ethernet.

A.1.3 Expanding Ethernets

Ethernet was designed to be easily expandable to meet the networking needs of a given site. Individual Ethernet segments can be linked together to form a larger Ethernet LAN system using a signal amplifying and retiming device called a repeater. A given Ethernet LAN can consist of merely a single segment, or of several segments linked with repeaters. Ethernet LANs can be linked together to form extended network systems using packet switching devices.

To help expand Ethernet systems, networking vendors sell devices that provide multiple Ethernet ports. These devices are known as hubs since they provide the central portion, or hub, of a star-wired media system. There are two major kinds of hub. The first kind provides repeater ports and is known as a repeater hub. Each port of a repeater hub links individual Ethernet segments together to create a single Ethernet LAN.

The second kind of hub provides packet switching based on bridging and/or routing ports and is known as a switching hub. Each port of a switching hub links separate Ethernet LANs together to create a larger network system composed of multiple LANs.

While an individual Ethernet LAN may typically support from a few up to several dozen computers, the total system of Ethernet LANs linked with bridges or routers at a given site may support many hundreds or thousands of machines.

A.1.4 Elements Of The Ethernet System

The Ethernet system consists of three basic elements: 1. the physical medium used to carry Ethernet signals between computers, 2. a set of medium access control rules embedded in each Ethernet interface that allow multiple computers to arbitrate access to the shared Ethernet channel,

and 3. an Ethernet packet, or frame, that consists of a standardized set of bits used to carry data over the system.

Computers attached to an Ethernet send application data to one another using high-level protocol packets, such as the TCP/IP protocol used on the worldwide Internet. These high-level protocol packets are carried between computers in the data field of Ethernet frames. The system of high-level protocols carrying application data and the Ethernet system are independent entities that cooperate to deliver data between computers.

A given Ethernet system can carry several different kinds of high-level protocol data. For example, a single Ethernet can transmit data between computers using the vendor-neutral TCP/IP protocols as well as the more vendor-specific Novell or AppleTalk protocols. The Ethernet is simply a trucking system that carries packages of data between computers; it doesn't care what is inside the packages.

For more information on Ethernet, see the on-line quick reference book, by Charles Spurgeon, through the WWW URL: http://wwwhost.ots.utexas.edu/ethernet/descript-10quickref.html.

A.2 Asynchronous Transfer Mode (ATM)

In some multi-hospital networks, ATM (Asynchronous Transfer Mode) technology is being used as a basis for sharing information along the continuum of health care. ATM[2] allows interoperability of information, regardless of the "end-system" or type of information. ATM is an "emerging technology" driven by international consensus, not by a single vendor' s view or strategy.

Historically, there have been separate methods used for the transmission of information among users on a Local Area Network (LAN), versus "users" on the Wide Area Network (WAN). This situation has added to the complexity of networking as user' s needs for connectivity expand from the LAN to metropolitan (MAN), national, and finally world wide connectivity. ATM is a method of communication which can be used as the basis for both LAN and WAN technologies. It is felt that over time as ATM continues to be deployed, the line between local and wide networks will blur to form a seamless network based on one standard-ATM.

Today, in most instances, separate networks are used to carry voice, data and video information-mostly because these traffic types have different characteristics. For instance, data traffic tends to be "bursty"-not needing to communicate for an extended period of time and then needing to communicate large quantities of information as fast as possible. Voice and video, on the other hand, tend to be more even in the amount of information required-but are very sensitive to when and in what order the information arrives. With ATM, separate networks will not be required. ATM is the only standards based technology which has been designed from the beginning to accommodate the simultaneous transmission of data, voice and video.

A.2.1 ATM Technology

ATM is available at various speeds from Megabits to Gigabit speeds. When information needs to be communicated, the sender *negotiates* a "requested path" with the network for a connection to the destination. When setting up this connection, the sender specifies the type, speed and other attributes of the call, which determine the end-to-end quality of service.

Another key concept is that ATM is a switched based technology. By providing connectivity through a switch (instead of a shared bus) several benefits are provided: 1) dedicatedbandwidth per connection, 2) higher aggregate bandwidth, 3) well defined connection procedures, and 4) flexible access speeds.

Using ATM, information to be sent is segmented into fixed length cell, transported to and re-assembled at the destination. The ATM cell has a fixed length of 53 bytes. Being fixed length allows the information to be transported in a predictable manner. This predictability accommodates different traffic types on the same network.

The cell is broken into two main sections, the header and the payload. The payload (48 bytes) is the portion which carries the actual information-either voice, data, or video. The Header (5 bytes) is the addressing mechanism.

A.2.2 ATM System Architecture

ATM is a layered architecture allowing multiple services like voice, data and video, to be mixed over the network. Three lower level layers have been defined to implement the features of ATM.

The Adaptation layer assures the appropriate service characteristics and divides all types of data into the 48 byte payload that will make up the ATM cell.

The ATM layer takes the data to be sent and adds the 5 byte header information that assures the cell is sent on the right connection.

The Physical layer defines the electrical characteristics and network interfaces. This layer "puts the bits on the wire." ATM is not tied to a specific type of physical transport.

A.2.3 The Status of ATM Technology

ATM has moved from concept to reality with products and services available today. The ATM Forum, discussed further in section 4.3.4, has sponsored interoperability demonstrations to prove the technology and continues to meet to discuss the evolution of ATM.

ATM coexists with current LAN/WAN Technology. ATM specifications are being written to ensure that ATM smoothly integrates numerous existing network technologies, at several levels (i.e., Frame Relay, Ethernet, TCP/IP). Equipment, services and applications are available today and are being used in live networks.

A.2.4 The ATM Forum

The ATM Forum was started in October of 1991 by a consortium of four computer and telecommunication vendors. In June 1994, the forum had over 700 members. Membership is made up of network equipment providers, semiconductor manufacturers, service providers, carriers and end users.

The Forum is not a Standards body. The ATM Forum is a consortium of companies that writes specifications to accelerate the definition of ATM technology. These specifications are then passed up to ITU-T (Formerly the CCITT) for approval. The ITU-T standard body fully recognizes the ATM Forum as a credible working group.

For more information on the ATM Forum and the ATM technology:

Email:	info@atmforum.com
WWW URL:	http://www.atmforum.com/

A.3 References

1. From Charles Spurgeon, WWW URL: http://wwwhost.ots.utexas.edu/ethernet/descript-10quickref.html
2. Obtained from WWW URL: http://www.atmforum.com/

Appendix B: Glossary of Telemedicine and Hospital Information Systems Acronyms

Acronym	Definition and Comments
ABI	Application Binary Interface
ACH	Automatic Clearing House
ACR	American College of Radiology
ADC	, Analogue to Digital Converter
ADT	Admission Discharge Transfers
ANSI	American National Standards Institute
APG's	Ambulatory Patient Groups
API	Application Program Interface
APM	Anatomical Pathology Module, part of an HIS
AR	Accounts Receivable
ARPA	Advanced Research Projects Agency
ASCII	American Standard for Code Information Interchange
ASTM	American Society for Testing and Materials
ATA	American Telemedicine Association, 512-480-2247
ATIS	Alliance for Telecommunications Industry Solutions
ATM	Asynchronous Transfer Mode, Automatic Teller Machine, Adobe Type Manager
AUI	Attachment Unit Interface, Ethernet transeiver cable between actual interface (computer) and the MAU
B-Channel	Bearer channel, ISDN channel with 64 kbps bandwidth (see PRI)
B/AR	Billings, Accounts Payable
BAI	Basic Access Interface, ISDN with two B and one D channels (2-64kbps, 1- 16 kbps), (2B+D)
BLOB	Binary Large Object
BNC	A common type of quarter twist connector for coaxial cable.
BRI	Basic Rate Interface-16kbps ISDN Channel
CAP	College of American Pathologists, Central Arizona Project
CCD	Charge Coupled Device, uses Photovoltaically generated packets of charge that are converted to pixels.
CCITT	Standards group now called ITU-T
CDR	Clinical Data Repository
CEN	European Standards Group
CEN/TC 251/WG4	Working on spec similar to HL7. (CEN and HL7 coordinate)
CEO	Chief Executive Officer
CHCS	Composite Health Care System
CHIN	Community Health Information Network
CIS	Clinical Information System
CLK	Clerk
COO	Chief Operating Officer
COPE	Combined Patient Experience, a laboratory medicine database
CORBA	Common Object Request Broker Architecture
COSI	Corporation for Open Standards International
COTS	Connection-Oriented Transport Service
CPE	Customer Premises Equipment
CPR	Computer-based Patient Record: Coronary Pulmonary Resuscitation
CPT	Current Proceedure Terminology
CPU	Central Processing Unit
CQI	Continuous Quality Improvement
CR	Computed Radiography
CSMA/CD	Carrier Sense Multiple Access with Collision Detection, Ethernet features
CT	Computed Tomography
D-channel	Delta-channel, ISDN channel with 16 kbps bandwidth (see BRI)
DDN	Defense Data Network
DEC	Digital Equipment Corporation
DG	Data General Corporation
DHCP	Decentralized Hospital Computer Program, used by DEC and CHCS
DICOM	Digital Imaging and Communications in Medicine
DINS	Digital Imaging Network Systems - Military term

Appendix B: Glossary of Telemedicine and Hospital Information Systems Acronyms

DIX	DEC Intel Xerox, initial standard for Ethernet (now an IEEE 802.3 standard)
DMSSC	Defense Medical Systems Support Center
DNA	Deoxyribonucleic Acid Sp?
DoD	Department of Defense
DoH	Department of Health
DRAM	Dynamic Random Access Memory
DRG's	Diagnosis Related Groups
DSOs	Digital voice channels, used with ISDN
DTE	Data Terminal Equipment, usually a computer that interfaces with Ethernet
DTS	Dietetics
DVA	Department of Veterans Affairs
Dx	Diagnosis
EDI	Electronic Data Interchange
EDIFACT	Electronic Data Interchange for Administration, Commerce, and Transport
ENR	Enterprise Network Roundtable, user group of ATM
EOC	Expense Operating Center ? ,an accounting term
EOQ	Economic Order Quantity
EPI	Enterprise Patient Index
EPROM	Electronically Programmable Read Only Memory
ESS	Executive Support System
FAQ	Frequently Asked Questions
FCS	Full Cover Slip
FDDI	Fiber Distributed Data Interface
FIFO	First In - First Out
FOE	Fiber Optic Enclosure
FOIRL	Fiber Optic Inter-Repeater Link, used with Ethernet
FOMAU	Fiber Optic Medium Attachment Unit, transceiver for Ethernet
FTP	File Transfer Protocol
FYI	For Your Information
GAO	General Accounting Office
GATT	General Agreement for Tariff and Trade
GHNet	Global Health Net
GL	General Ledger
GNA	Global Network Academy
GNP	Gross National Product
Gopher	animated contraction of "go-for" looks for subject or words of interest on the NET
GP	General Practitioner
GPIP	General Purpose Image Processing
GPR	Graphical Patient Record
GRIPE	Group for Research in Pathology Education
GUI	Graphical User Interface
GYN	Gynecological
HAF	Hyperalimentation Fluids
HCIS	Health Care Information System
HCO	Health Care Organization
HCTG	Health Care Technology Group
HDTV	High Definition Television
HIS	Hospital Information System, Health Information System
HISPP	Health Informatics Standards Planning Panel
HISPP	Health Informatics Standards Planning Panel, formed by ANSI
HISS	Hospital Information Support System
HITS	Health Innovations in Technology Systems, yearly award given by the Henry Ford Health System
HL7	Health Level 7
HMO	Health Maintenance Group
HTML	Hyper Text Markup Language

Appendix B: Glossary of Telemedicine and Hospital Information Systems Acronyms

IBM	International Business Machines
ICD	billing code used for various cases?
ICU	Intensive Care Unit
ID	Individual Identifier
IDN	Integrated Digital Network
IEC	Image Exchange Committee, developing Pathology extension to DICOM
IEEE	Institute of Electrical and Electronic Engineers
IHID	Inter Hospital Image Distribution
IPA	Independent Physicians Association, or Independent Practice Association
ISA	International Standards Association, Instrumentation Society of America
ISAM	Indexed Sequential Access Method, (used with data bases)
ISDN	Integrated Services Digital Network
ISIS	Information System-Imaging System
ISO	International Standards Organization
IT	Information Technology
ITU-T	International Telecommunications Union-Telecommunications, sets ISDN standards
JPEG	Joint Photographers Expert Group
JWG-CDM	Joint Working Group, Common Data Model
LAB	Laboratory
LAM	Lymphangioleiomyomatosis
LAN	Local Area Network
LANL	Los Alamos National Laboratory(ies)
LEOS	Low Earth Satellite
LIFO	Last In - First Out
LIS	Laboratory Information System
LM	Laboratory Module, part of an HIS
LOS	Length Of Stay
LSDA	Line Scan Diode Array, provides high resolution large image scanning capability
MAC	Medium Access Control, provides access when available from each Ethernet station
MAR	Medication Administration Record
MAU	Medium Attachment Unit, Transceiver for Ethernet that interfaces between computer and the medium.
MD	Medical Doctor
MDC	MUMPS Development Committee
MDF	MD Forms
MDI	Medium Dependent Interface, Ethernet hardware that connects directly interfaces to the medium.
MDIS	Medical Diagnostic Imaging Support system - used by Military.
MDL	MD Lookup
MDR	MD Retrieval
MIS	Medical Information Systems, Management Information System
MPI	Master Patient Index
MRI	Magnetic Resonance Imaging
MRN	Medical Record Number
MSDS	Message Standards Developers Subcommittee, health care message interchange stds, formed by HISPP
MTF	Medical Treatment Facilities - Military Term
MUMPS	Massachusetts (Gen. Hosp.) Utility Multi Programming System, Prog. Lang. used by SAIC & some Hosp.
NCPDP	National Council of Prescription Drug Pharmacies
NEMA	National Electrical Manufacturers Association
NET	Short for Internet
NHS	National Health Services?
NII	National Information Infrastructure, goal to provide equable information services to all Americans
NII-HIN	National Information Infrastructure-Health Information Network
NIST	National Institute of Standards and Technology
NMF	Network Management Forum
NOS	Not Otherwise Specified
NPS	Non Printed Specifics

NRS	Nursing
ODA	Optical Disk Archiving system
ODJ	Optical Disk Jukebox, Optical media (platters) for high density digital storage
OLE	Object Linking and Embedding
OMG	Object Management Group, (responsible for CORBA standards)
OSI	Open System Interconnection, seven layers of of hierarchy
OT&E	Operational Test and Evaluation
PACS	Picture Archiving and Communications System - Used by Military
PAD	Patient Administration Department?
PAS	Patient Appointment Scheduling
PBXs	Private Branch Exchanges
PC	Personal Computer
PCI	Patient Care Inquiry, high speed buss that carries information in PC's and Power Macs
PCM	Personal Computer-Microscope, provides workstation features with digital images
PET	Positron Emission Tomography
PHO	Physician Hospital Organization
PHR	Pharmacy
PMED	Portable Medical Entry Device
PO	Purchase Order
POE	PowerOpen Environment
PPO	Preferred Provider Organizations
PRI	Primary Rate Interface-ISDN 23 ea, 64 kbps channels + one 64-kbps D-channel
PRO	Peer Review Organization
PtCT	Patient Care Technologies, Inc.
QA	Quality Assurance
QC	Quality Control
QTD	Quarter To Date
R&D	Research and Development
RAD	Radiology
RAID	Redundant Array of Inexpensive Disks
RBOCs	Regional Bell Operating Companies, the 7 Baby Bells
RBRVS	
RGB	Red Green Blue, a TV full color generating scheme where all color is obtained by addition of R,G,B
RIS	Radiology Information System
RM	Reference Model, Radiology Module, part of an HIS
RN, R.N.	Registered Nurse
RNA	Ribonucleic Acid
RTE	Remote Terminal Emulation
SAIC	Science Applications International Company
SCSI	Small Computer Standard Interface, pronounced "scuzzi"
SDC	Surgical Day Care
SDOs	Standards Developing Organizations
SMTP	? , information protocall
SNMP	
SNOMED	Systematized Nomenclature of Medicine
SOW	Statement of Work
SQL	Structured Quiry Language
SRDRG's	Severity Refined Diagnosis Related Groups
SSN	Social Security Number
T1	Communication lines with 1.54Mbt/sec transmission rate
TA	Terminal Adapter, interfaces with ISDN
TAMC	Tripler Army Medical Center
TCP/IP	Transfer Control Protocol, Internet Protocol
TDS	? , Total Dissolved Solids
TE	Terminal Equipment, devices using ISDN to transfer information

Appendix B: Glossary of Telemedicine and Hospital Information Systems Acronyms

TELNET	Information Protocall
TM	Telemedicine
TQM	Total Quality Management
TRP	Technology Reinvestment Project
UR	Utilization Review
URL	Universal Resource Locator
VA	Veterans Administration
VAR	Value Added Reseller
VRAM	Video Random Access Memory
WAN	Wide Area Network
WHIN	Wisconsin Health Information Network
WOM	Write Only Memory. Useful for storing your mother-inlaw's address
WORM	Write Once Read Many - Type of memory
WSU	Work Storage Unit, usually very high density digital storage may have fiber optic data transmission.
WTO	World Trade Organization
WWW	World Wide Web, graphical interface with hypertext used on the NET
XIWT	Cross-Industry Working Team, working on framework for the National Information Infrastructure
YTD	Year To Date

5. PATHOLOGY IMAGES AND INFORMATION SYSTEMS

This section consists of information on various anatomic pathology software and on a search for pathology images on the Internet.

5.1 Anatomic Pathology Modules

Information on anatomic pathology software modules was collected from telephone interviews with individuals at the various companies that provide them

5.1.1 Phil Mullarky, Sunquest Information Systems Inc., June 12, 1995

The module produced by Sunquest is called the *FlexiLab Anatomic Pathology/Cytology System.* It is a stand alone system in which the HIS system is built "from scratch" with its own pathology module. There are a total of 250 installation sites.

5.1.1.1 Imaging

The *FlexiLab Anatomic Pathology/Cytology System* is not capable of handling images as of right now, but the company is planning on it in the future. Mr. Mullarky stated that the images will be digital and will be in color. He said that you "must have color if you are working with pathology." The images stored under this system will be referenced to/coincide with cases from patients.

According to Mr. Mullarky, the storing capacity of the system is unlimited, and will be determined by the type of disk used.

Images will be able to be shared by pathologists. When asked specifically how the inquiries will be made, Mr. Mullarky just said the images will be referenced by a case. A local area network will be used, and no data rate (pixels/sec. or images/sec.) has been determined yet.

5.1.1.2 Voice

Sunquest is currently in the process of installing voice recognition with Kerzweil.

5.1.1.3 User Interface

The FlexiLab Anatomic module utilizes a mouse and a keyboard.

5.1.1.4 Host Computers

Sunquest supports UNIX, VM, and VMS platforms. As for the types of microprocessors, Mr. Mullarky said that Digital and IBM were used.

5.1.1.5 Cooperation

Sunquest is not working with any professional societies and/or government agencies while developing their system. They are, however, inspected by the FDA.

As far as working with us as we develop our workstation for pathology, Mr. Mullarky said that that was "to be determined." He stated that we might be on the same path as their company, and could not answer the question at the moment. He will be sending some literature on their system for us to review.

5.1.2 Nancy Vetter, Marketing Manager of Dynacor Inc., June 13, 1995

The pathology module produced by Dynacor Inc. is called the *PREMIER Series*. It can be a stand alone system, but Dynacor usually sells it with a clinical laboratory information system . It can also interface with hospital information systems. There are a total of eight installation sites.

5.1.2.1 Imaging

The system Dynacor uses is the IBM AS/400 System. It has the capability to handle images, but Ms. Vetter stated that no one wants to use images yet, so they have not implemented it into their system. The images would be digital and would be in color, Ms. Vetter assumed. As far as the images being used for reference or for patients files, Ms. Vetter said that at the design level, there was the capability for both.

Mr. Vetter did not know any information about the potential storing capabilities of the system. She said those questions would have to be directed toward the Development Manager.

The images will be shared between pathologists upon authorization. Ms. Vetter said that she assumed pathologists would want to have this built into their system. The images would be shared by a file server, and would be over either a local are network or wide are network. The type of network used would depend on the institution.

5.1.2.2 Voice

The *PREMIER Series* does not have voice yet, but does have the capability of implementing it. Ms. Vetter stated that voice was not a priority and therefore not utilized. If voice is installed, it will most likely be voice recognition and synthesis.

5.1.2.3 User Interface

Currently the module utilizes only a keyboard, but has "hot spots" for the mouse.

5.1.2.4 Host Computers

Dynacor supports IBM type computers (the AS/400). Ms. Vetter said that if someone wanted microprocessors, IBM compatibles would be used.

5.1.2.5 Cooperation

Dynacor does not work with any professional societies and/or government agencies in the development of their system. They work with user space (with their own organization). Occasionally they work with a new client or focus group (two or more clients).

Ms. Vetter stated that they would very much like to work with us in the development of our workstation for pathology. In addition, she has sent some literature about their company and the anatomic pathology module for us to review.

5.1.3 Mary Wehlacz, Citation Computer Systems Inc., 6-14-95

The pathology module produced by Citation Computer Systems Inc. is called *Citation APS*. It is developed by building a laboratory information system (LIS) with an AP module that can be added on. It is not a stand alone system. There are 20 installation sites.

5.1.3.1 Imaging

Citation APS does not handle images yet, however, the company is actively looking into it. Ms. Wehlacz was not certain if the images would be digital or analog, but said that they would be in color and had the possibility of being either reference images or new images for patients files.

Ms. Wehlacz did not know what the storing capacity of the module would be for images.

Images will be shared between pathologists with a file server under *Citation APS.* The images will be on a network that PC's will be able to access when attached.

5.1.3.2 Voice

The company's system does not have voice. They are looking into voice recognition, but Ms. Wehlacz stated that their systems are not ready for it yet. She said they have tested voice but the system has problems recognizing certain words. When it does not recognize a word, it will form a list of words to choose from.

5.1.3.3 User Interface

Currently *Citation APS* utilizes a touch screen, mouse, and keyboard for its system.

5.1.3.4 Host Computers

The platforms supported by Citation APS are a local area PC based client servers. If the company were to use microprocessors, they would use Intel and have a minimum of 46 processors.

5.1.3.5 Cooperation

Citation Computer Services Inc. works with customers from a variety of hospitals (teaching, etc.) in the development of their pathology module.

Ms. Wehlacz stated that they would be very interested in working with us in the development of our pathology workstation. She is sending literature on their system to Kensal for us to review.

5.1.4 Mark Hughes, Cerner Corporation, 6-21-95

The name of Cerner Corp.'s pathology module is *PathNet Anatomic Pathology. PathNet* has two different architectural features of the module. The first is the traditional mainframe (stand alone) system. Mr. Hughes explained that the hardware for this system is too expensive to actively market imaging with, and is not cost effective for clients. Only two clients currently use the system as a stand alone system. Clients must purchase both the PathNet Core and the PathNet Pathology System in order to use it as such. Mr. Hughes added that although the clients do like the stand alone system, very few utilize it. The second architectural feature of the module is a client server system where PC's can be purchased and used. This type of system is not a stand alone system. Cerner Corp. is currently in a transitional phase of switching over to the client server architecture. This system will use Microsoft Windows, which makes images easier to manage, along with the possibility of using real-time. This client server architecture will cost less because the hardware will cost less. Currently, there are 420 installation sites of the traditional mainframe system.

5.1.4.1 Imaging

Cerner Corp. has experimented in imaging with *PathNet Anatomic Pathology.* They worked in conjunction with Sony and Baylor University in image capturing with a system they referred to as

CPP, Cerner Pathology P.A.C.S (picture archiving system). With a camera mounted on top of a microscope, they would capture a microscopic image, save the image onto a disk, and then transfer it to a remote site within the hospital. A monitor was placed in a surgical suite and used as a communication vehicle between the surgeon and a pathologist. The system worked very well and the doctors liked what they saw, Mr. Hughes said. The diagnostic quality of the images were also approved by the doctors who used the system.

The images in this experiment were digital and in color (Mr. Hughes knew that it was greater than 256, but could not give an exact number). Mr. Hughes did not know the size of the images (in pixels) or the number of bits per pixel. In future use, the images on the system could be used either for reference or as images for patient files.

The storing capability of the pathology module will depend on the medium device. Currently the company uses super high density disks from Sony, which store 20 megabytes a piece.

The method of indexing employed may be a number of things. Images may be indexed by patient number, social security number, or patient name, for example. In addition, Mr. Hughes added that the SNOMED coding may be used.

Retrieval of the experimental images at Baylor took an average of 20-30 seconds. Those images captured will be stored permanently (for legal reasons of the experiment). Mr. Hughes speculated that images captured in the future will be stored for as long as the storage device will allow.

Cerner Corp.'s module is not set up for networking together, so images may not be shared between pathologists in that sense. Mr. Hughes stated that the way sharing works currently is that pathologists walk up to one station which stores the images and pulls them up from that station. There is no networking of the images though. If networking is implemented, Mr. Hughes said that both a local area network and a wide area network could be used. He did not know what the data rate would be.

5.1.4.2 Voice

Cerner Corp. has not developed voice for their system yet, but it does have the capability to be used. If they do use voice, it will be voice recognition. The company did do an interface to Covington Hospital in Virginia using the Kerzweil System (voice recognition). Problems were encountered, however, when the system did not recognize a word. When this happened, it would pull up a list of words for the pathologist to choose from.

5.1.4.3 User Interface

PathNet Anatomic Pathology utilizes a mouse and a keyboard.

5.1.4.4 Host Computers

The platforms supported by the module are the IBM Risk/6000 Box and DEC Alpha (along with other Deck products). The company does not use microprocessors at the moment, but will use Intel for future products.

5.1.4.5 Cooperation

Cerner Corp. invites clients (experts) to review and test their systems. These experts are usually pathologists, histotechs, or cytotechs from larger universities.

Mr. Hughes showed great interest in working with us as we develop our pathology workstation. He stated that he thought it would be a great option to explore. He is going to send some literature on their CPP system for us to review.

5.1.5 Carol Donohue, Director of Marketing, CoMed, July 2, 1995

The name of CoMed's anatomic pathology module is *CoPath.* It is a stand alone system. In regards to the March 1995 *CAP Today* article, *CoPath* has 186 installed sites, three of which are in Arizona (Mayo Clinic in Scotsdale; Scotsdale Memorial; and John C. Lincoln in Phoenix).

5.1.5.1 Imaging

Currently CoPath can handle "very minimal hand drawn images, such as organ diagrams." Ms. Donohue is not sure if the images are digital or analog, but stated that they are scanned with an HP Scanjet. She assumes they are digital. The size of the images is very limited because they must fit into a certain space on the patient reports. The exact size is not known. Since the images are used mainly for standard reports that are passed from doctor to doctor, Ms. Donohue said that they are strictly in black and white. The doctors did not want color.

The images are stored in "chunks," a months database at a time. They are stored in a textbox and then uploaded into the months database. Images are usually associated with a specimen number. The file is structured in a hierarchical structure. Ms. Donohue was unsure if the images could be retrieved for viewing purposes, unless they were looked at under WordPerfect. Images are stored permanently as of right now.

Ms. Donohue mentioned that they can interface to external systems which can handle other, larger images.

CoPath is a multi-user system, in which images can be shared through a file server with WordPerfect. Otherwise, a lat protocol is used to get at information. A 232 connection is used for this. The system can run with other applications, but it is not a true network. She did not know the data rate of the system.

5.1.5.2 Voice

The CoPath system does not have voice, but interfaces to other systems which usually have voice recognition. If the other system also has synthesis, then that is implemented also.

5.1.5.3 User Interface

The pathology module utilizes a touch screen and a keyboard.

5.1.5.4 Host Computers

The platforms supported by *CoPath* are PC, IBM RISC, and VAX mini-systems. All microprocessors are Intel.

5.1.5.5 Cooperation

Ms. Donohue stated that they do not work directly with any professional societies or government agencies in developing their system. They do meet regulations, however, and work with the College of American Pathologists (CAP) occassionally.

Ms. Donohue was very hesitant in giving any sort of commitment to working with us as we develop our workstation. She was concerned mainly about competition. She is sending literature on their system for us to have on file.

5.1.6 John Edmondson, VP Sales of Community Health Computing Inc., July 7, 1995

(Mr. Edmondson is forwarding the information to Fred Tillman who is the Development Manager of CHC.)

Community Health Computing Inc. (CHC) has two pathology systems. Their oldest system is about 20 years old and is called LabCare. It is a stand alone system and is what a majority of their clients use. They are in the process of building a newer system, however, called LabStat. It too will be a stand alone system, and 70% of it is already engineered. It is currently in one beta site. The questions asked in the interview were answered in regards to the newer module. There are a total of 91 installations for the older system.

5.1.6.1 Imaging

The LabStat module will be able to handle images when it is completed. The images can be either digital or analog, but Mr. Edmondson said they will probably be primarily digital. They will also be produced in color. Mr. Edmondson explained that the way their system will work is that the images will be created somewhere else and then transferred to their system. Therefore, the images will probably be used for reference. As far as the size of the images, that is unknown. The images will be used for reporting clinical information and associated with a document. Mr. Edmondson stated that they will not be used for diagnosis, just for informational purposes.

Mr. Edmondson did not know the answers to the questions regarding storing capacity and suggested that they be asked to Mr. Tillman.

The images can be shared between pathologists if they allow for it (a matter of security). Mr. Edmondson was not sure how those images would be shared though. Their system will use both a local area and a wide area network. Mr. Edmondson explained that they must build in accordance to how things are on the information highway, and that is why both networks will be used. He did not know what the data rate of the network would be.

5.1.6.2 Voice

LabStat has no application for voice today because of limitations encountered (such as it can't do conversations or recognize certain words). Mr. Edmondson stated that cytology would probably benefit more from voice because they use just one word or number to often describe a case (much easier to understand).

5.1.6.3 User Interface

CHC's module will utilize a mouse and a keyboard. The keyboard will be either a terminal or character driven interface for Windows.

5.1.6.4 Host Computers

The platform that is currently supported in the single beta site of the new system is Hewlett-Packard. They will move onto others in about a year or so. Microprocessors are from Intel.

5.1.6.5 Cooperation

CHC does not market to federally funded agencies because they did not like the older system. Other than that, they do work with clients and consultants in the development of their system.

There are no installations of LabStat in Arizona, but there are a couple of the older system, LabCare. The ones Mr. Edmondson could remember were Sun Health Boswell Hospital in Sun City and St. Joseph's in Phoenix.

Mr. Edmondson said that they would be interested in working with us as we develop our workstation. He stated that they would like to capture what we do, and that they are planning to install their system in a large, highly recognized institution in 1996 (not through the DoD). He also explained that they will be starting to build their software in six to nine months, so now would be a good time to interface and work together.

Mr. Edmondosn is sending literature to us regarding their systems.

5.1.7 Dan Callaher of MEDITECH (Medical Information Technology Inc.), July 7, 1995

(I spoke with Dan Callaher who is one of the Marketing personnel, but he was going to pass the letter and article onto Larry Gay who is another Marketing personnel who handles companies in the Southwest US.)

The name of MEDITECH's pathology module is *Meditech Anatomic Pathology*. It can be built as either a stand alone system or to be integrated into HIS systems. There are 26 applications with which it can be integrated, and 364 installation sites.

5.1.7.1 Images

Mr. Callaher stated that *Meditech Anatomic Pathology* module can handle images, but does not right now because of limited technology. He said that when the proper resolution, monitors, and so on are figured out on the technological end and become affordable, then the systems will be able to handle images. As far as whether the images will be digital or analog, Mr. Callaher said that which ever produces the best quality or resolution is what they will use. He applied the same statement to the question of color or black and white images. Depending on the cost, images will be associated with patient files, but will also be able to be used for reference.

As far as storing capability, Mr. Callaher said that there would be no limit on how many images the module would be able to handle. He was not sure about the method of indexing, but guessed it might be in a sequence query language. Since their system is hierarchical right now, he guessed that that was how the file would also be structured. The retrieval of images and the amount of time the images are saved for will depend on the technology.

Mr. Callaher stated that images could be shared between pathologists. They would be shared on a "network of some sort," he said. When asked if they would use a local area network or a wide area network, Mr. Callaher said that it did not matter. He did not know what the data rate would be.

5.1.7.2 Voice

MEDITECH's pathology module does not have voice, but they do interface to the Kerzweil product which uses voice recognition.

5.1.7.3 User Interface

The *Meditech Anatomic Pathology* module primarily utilizes a keyboard, but can also use a mouse.

5.1.7.4 Host Computers

Currently MEDITECH supports DEC and Data General platforms, but they are moving to a new system of Windows, the NT Operating System. The microprocessors they use are Intel.

5.1.7.5 Cooperation

MEDITECH works with "everything and everyone" as far as professional societies and government agencies. They have over 800 installations throughout the US., and have several in Arizona. Mr. Callaher knew that their system was implemented in the St. Mary's and St. Joseph's Hospitals (Carondolet), but was not sure of the others. He said to check with Mr. Gay for further information where that was regarded.

As far as working with us in the development of our pathology workstation, Mr. Callaher said that we must check with the joint systems people.

They do have literature available to send to us. Mr. Callaher again said that Larry Gay will call regarding that.

5.1.7.6 Telephone Interview with Larry Gay, 8-31-95

While interviewing Mr. Gay, he reiterated a lot about the system which Mr. Callaher had already stated. Their system does not handle images at the moment, but they are planning on having them in the future. The types of images they will carry will be any kind of digitized image. Images will be in color he assumed. The storage capability of the module will not be limited, he guessed, and will depend on the hardware from the third party vendor. The type of indexing they currently employ for their reports, not images, is proprietary. Mr. Gay estimated that the retrieval time of images will be much like the retrieval time of the reports - "seconds." The company uses optical storage, and therefore stores everything permanently.

Images will be able to be shared between pathologists. They will be done so through an optical or jukebox file server. The type of network they currently use is the TCPIP mode. In addition, both a wide area and local area network will be used for images. Mr. Gay did not know the data rate off hand.

Again, the system does do an interface to Kerzweil for voice recognition. The system also primarily utilizes a keyboard. The platforms supported are DEC and Data General, while the microprocessors are Intel. Mr. Gay said that the amount of memory on the hard drive varies depending on the institution supplying it.

Mr. Gay also confirmed that they do have installations in Arizona. Though he would not give specific names of hospitals, he said they do have a corporation set up with Carondolet.

Literature is being sent for us to review.

5.1.8 Steve Tablak, Marketing Manager of Tam Support Services, July 11, 1995

Tam Support Services is one of the smaller companies contacted in this interview, with 34 installations of their module. The name of their module is *PowerPath Anatomic Pathology System* and it is a stand alone system.

5.1.8.1 Imaging

As far as handling images, the *PowerPath Anatomic Pathology System* can only incorporate them into a final report. The images are digital, and the size of them depends on whatever the customers want to do. Mr. Tablak explained that most of the images are gross images or diagrams, and therefore the size is usually small. He said that most images are not viewed by doctors for diagnostic reasons, and only one or two customers use them for reference. He also stated that it does not matter if the images are in color or in black and white, as long as they are supported by Windows.

The storing capability of the module is part of the word document (Mr. Tablak did not say how many images their system could store based on that information). Mr. Tablak stated that the method of indexing employed does not matter, but they typically use accession numbers. In addition, files are structured by relations. The retrieval time of images depends on the computer and if the images are compressed, but Mr. Tablak stated that this feature is not used a lot. Since images are used for final reports, they are stored permanently.

The images can be shared between pathologists, and are done so with the Novell networking system. A local area network is used, and the data rate is 10 megabits per second.

5.1.8.2 Voice

PowerPath Anatomic Pathology System interfaces to Kerzweil to implement voice recognition on the system.

5.1.8.3 User Interface

Tam Support Services module utilizes a touch screen, mouse, and keyboard, with primary emphasis on the mouse and keyboard (Windows based).

5.1.8.4 Host Computers

Mr. Tablak stated that they can support any PC type platform. More specifically, he mentioned Novell, NT, DEC, and HP. The microprocessors they use are Intel or DEC alpha.

5.1.8.5 Cooperation

Tam Support Services works with teaching institutions in the development of their system. Mr. Tablak mentioned that they typically work with highly recognized institutions, such as Stanford. They do not currently have any installations in Arizona.

As far as working with us in the development of our workstation, Mr. Tablak said that they would like to talk to us about it. More importantly, he said it depends on if the teaching institutions they are working with like what we are doing.

Mr. Tablak is having his secretary send some information to us about their system.

5.1.9 Dennis Hart, Computer Trust Corporation, July 12, 1995

The name of Computer Trust Corporation's pathology module is *SURGE*. *SURGE* is a stand alone system, with the ability to interface to other HIS systems. There are 34 installations of this module.

5.1.9.1 Imaging

SURGE cannot handle images and the company is not planning on adding images to it.

5.1.9.2 Voice

The system does not have voice, but has the capability to obtain it. Computer Trust Corp. currently has a handshake deal with Kerzweil, which uses voice recognition. The reason they have not implemented voice is that it is too expensive, Mr. Hart said.

5.1.9.3 User Interface

The *SURGE* module utilizes only a keyboard.

5.1.9.4 Host Computer

The platforms supported by the module are the Novell System and UNIX. The microprocessors are all Intel.

5.1.9.5 Cooperation

Computer Trust Corporation does not work with any professional societies or government agencies in the development of their system. The man who built this system and the company, Dr. David Liberman, has a lot of experience in the necessary fields, and oversees everything that goes on. Occasionally they do refer to some consultants.

There are no *SURGE* systems anywhere in Arizona.

Mr. Hart feels that they do not cater to the same people that we work with, and therefore do not have resources that could really help us out. He did state that they might be willing to possibly help in our effort and codevelop for a specific company if requested to do so. He is sending literature on their module.

5.1.10 Dan Hellman, Technical Director, Anatrol Pathology Computer Systems, Aug. 23, 1995

Mr. Hellman is the technical director of the Anatrol Pathology Module. It is capable of being either a stand alone system, or interfacing to already existing software for HIS systems. If interfacing to an already existing system, Anatrol is capable of interfacing to whatever HIS system the hospital has (no preferences).

5.1.10.1 Imaging

Anatrol is not yet capable of handling images, but Mr. Hellman said that they are definately planning on it. They will carry any type of image the user would like (gross, microscopic, X-ray) as long as the file is in the proper industry format (GIF, JPEG, etc.). More than likely, the images will also be digital. Mr. Hellman explained that everything is being put on a binary or "blob." As far as color or black and white images, it will be whatever the client prefers. The software that the system has to handle the images will be canned. Mr. Hellman explained that he likes to attach to whatever already exists.

The storing capability of the module will be limited by the hardware. Text headers will be used as the method of indexing, and more than likely the images will be coded for by the SNOMED system. This is how the file will be structured also. As far as the retrieval time for the images and the length of time they will be saved for, that will all depend on the functions of the hardware.

The sharing of the images will have to be determined by the particular department who employs their system, Mr. Hellman said. There will be a data lock and a confidentiality lock on their system, so it's up to the department to determine if the images will be shared or not. If they are to be shared, a data base server will be used that utilizes all kinds of networks. In addition, both local area networks and wide area networks can be used. Mr. Hellman explained that they like to try to remain as independent from hardware as possible so as to accomidate a preferred type of set-up when the time comes. The data rate will also depend on the file being used.

5.1.10.2 Voice

As of right now, Anatrol is working on voice in conjunction with Kerzweil. They are, however, working more intently on the use of hand and pen based computers.

5.1.10.3 User Interface

The main type of interface the module utilizes is the pen right now. They are, as mentioned above, working on voice and do use the keyboard, mouse, and touchscreen.

5.1.10.4 Host Computers

Because they remain independent of hardware, Anatrol does not really support any specific platforms. They do use UNIX and NT, but only on a text basis. As far as microprocessors, Mr. Hellman said that about 85% of their clients use Intel, with a couple others using Risk.

5.1.10.5 Cooperation

Mr. Hellman said that they do occassionally work with professional societies in the development of their system, but not in a big way. They mainly work with CAP, but that is from a licensing point of view.

Anatrol does not have any installations in Arizona currently. Some states that do use their system are Texas, Oklahoma, and California.

Mr. Hellman said that they would definately be interested in working with us in the future. He would like to be kept abreast of the progress we are making and everything else that is going on. He is sending literature on their older system to us to lookover and keep on file.

5.1.11 Terry Johnson, Accupath, Aug. 24, 1995

The *ACCUPATH Anatomic Pathology System* is a stand alone system as of right now. It does have the ability to interface to ORACLE and is also motim interfacible. Mr. Johnson explained that there is just no demand for interfacing at the moment. This product is ORACLE based and is on a UNIX box.

5.1.11.1 Imaging

The pathology module does not handle images, but does carry such things as graphs and charts. Mr. Johnson said that they might consider carrying images if they received a large hospital account. If that does occur, the types of images they would carry would be cytology, Pap, and microscopic, which he feels is the main interest right now. The images would be in color and would most likely be digital.

If and when the company decides to carry images, they would not keep the images in the ORACLE database. Mr. Johnson explained that they would use a pointer to an external reference. Therefore, he did not know what the storing capability of the module would be.

Mr. Johnson also said that the images might possibly be shared between pathologists. He felt that it had commercial applications. He also felt that a wide area network would have to be used.

5.1.11.2 Voice

The *ACCUPATH Anatomic Pathology System* does not have voice. Mr. Johnson said that there is no call for it and he does not really see a reason for having it.

5.1.11.3 User Interface

ACCUPATH's system utilizes just a keyboard.

5.1.11.4 Host Computer

The platforms that ACCUPATH supports are UNIX and ORACLE. They are a licensed ORACLE resaler.

When asked about the amount of memory on the hard drive, Mr. Johnson explained that they use 386's.

5.1.11.5 Cooperation

ACCUPATH does not really work with any professional societies or government agencies in the development of their system. Since they are the main users of their product, there is no need for any outside advice yet. Mr. Johnson said that they do sell there system to some small hospitals, but they do not aid in the development of the system.

ACCUPATH does not have any installations in Arizona. They do have a beta site in Fresno, CA at Hadden Laboratories. There they work with Dr. David Hadden who does anywhere from 50-60,000 Pap Smears a year and approximately 5000 surgical slides a year.

Mr. Johnson said that they would be interested in working with us if they could find a way to cover the costs. His primary interest seemed to be with Pap Smears. Mr. Johnson also said he was puzzled by how we could possible interface our two systems.

5.1.12 Denise Smith, Marketing Manager, Advanced Laboratory Systems, Aug. 24, 1995

The name of this pathology system is *PATHLAB Anatomic Pathology*. It is both a stand alone system and an interfacible system. When interfacing to HIS systems, the one most commonly used one is the HL7 format.

5.1.12.1 Imaging

The *PATHLAB* system does not handle images currently. Ms. Smith said that they could add the feature to their system, but will not do so in the near future.

5.1.12.2 Voice

The system also does not have voice. Ms. Smith said that they did some testing with it but didn't like it very much.

5.1.12.3 User Interface

As of right now, their system utilizes only a keyboard. They are planning on adding the mouse by next year.

5.1.12.4 Host Computers

The type of platform that the *PATHLAB* system supports is UNIX. The microprocessors they use are Intel.

Ms. Smith did not know off hand how much memory was on the hard drive or RAM.

5.1.12.5 Cooperation

Ms. Smith said that they worked with only some hospitals and pathologists in the development of their system.

She did not know if they had any installations in Arizona other that St. Luke's up in Phoenix. She thought that that system was just the AP system too.

Ms. Smith said that they were not really interested in working with us in the future. She explained that their main priority for next year is a client server situation. She also explained that pathologists have not been asking for imaging, therefore they are not worrying about it right now.

5.1.13 Mary Ann Lafayette, Cytology and Pathology Services Inc., Aug. 24, 1995

The Cytology and Pathology Services Software is a stand alone system. The company only has three installation sites at the moment.

5.1.13.1 Imaging

The system does not carry images, but Ms. Lafayette said the issue has been discussed. She also explained that pathologists have not been pushing for it.

There was no information on what kind of images they might possibly carry (such as digital, color, reference, etc.). There was also no information on the storing capability of their system because the hardware is purchased by the user.

5.1.13.2 Voice

The system does not have voice yet, but they are working on it. The doctor in charge of the company is currently re-engineering a voice system by the name of *Lantastic.*

5.1.13.3 User Interface

Currently the pathology module only uses a keyboard. Mr. Lafayette explained that this is still the fastest for transcriptionists. She also explained that other areas of the system that use Windows utilize the mouse, but that is a very small number and only comes about upon request.

5.1.13.4 Host Computers

The Cytology and Pathology Services Software is strictly DOS based or PC based. It operates in any network (such as Novell). They do not produce the hardware. That is up to the purchaser.

5.1.13.5 Cooperation

The company has specifically developed their system for two hospitals in Alabama to use. Those are the only people they have worked with in its development. Ms. Lafayette was also just informed that some University of Alabama cytotechs will be coming in soon to look at her system and possibly work with it. There are no installations in Arizona.

When asked if they might be interested in working with us in the development of our system, Ms. Lafayette said that she would pass the information on to the pathologist in charge to see what he thinks. A couple of days after this interview was conducted, Dr. Donald(?) Canley, the pathologist in charge, did contact me with some constructive criticism about what we are doing. He said that he was intrigued by what we were doing but also said he didn't think it would work. His main reason for this was that we would have to improve the resolution greatly in order for it to become effective. In order to do this, he suggested that we would have to get the pixels much smaller in the images and that we would have to make the diodes 1/4000 as small as they are right now to achieve that goal. He also explained that he may not completely comprehend what we are doing and that this might work. He would like to be updated on our progress in the future.

5.1.14 Stan Gordon, President of Cortex Medical Management Systems Inc., Aug. 29, 1995

The name of Cortex Medical Mgt.'s pathology module is *The Gold Standard.* It is mainly a stand alone system, but has the ability to interface to HIS systems. The most common HIS systems the company has interfaces to are SMS and HBO&C. There are 67 installations of this pathology module.

5.1.14.1 Images

The Gold Standard does not handle images yet, but the company is definitely planning on adding this feature to their system. The types of images handled will be micrographs, Mr. Gordon said. In addition, the images will be digital and will be in color. The images will also be used mainly for patient filing and not for reference. The software the company uses right now is canned, not in-house.

Mr. Gordon explained that their product is primarily in DOS right now, but will be switched to Windows by the fall. (They hope to have a beta site by the fall).

The storing capability of the module is unlimited. Mr. Gordon explained that they will use CD jukeboxes for storage, which usually does not have a limit to it. The method of indexing and file structure will be a sequel server and will be built by them. When asked about the retrieval time of an image, Mr. Gordon estimated that it would take no longer than about five seconds. In addition, the company will store the images permanently.

The images will be able to be shared between pathologists, and probably done so through an image file server. Mr. Gordon said that the networks would probably be EtherNet and Microsoft NT. Both wide area networks and local area networks will be used, but the majority will be local area because that is what most of their clients use.

Mr. Gordon did not know the data rate of the network.

5.1.14.2 Voice

Mr. Gordon did state that their system will have voice by the fall (when they get their beta site). It will be voice recognition.

5.1.14.3 User Interface

The Gold Standard utilizes a mouse and a keyboard.

5.1.14.4 Host Computers

The platforms they support and microprocessors they use are Intel. The 586's will be the standard. As far as the memory on the hard drive and RAM, Mr. Gordon said it was probably about 300MB on the local and 2GB on the file server.

5.1.14.5 Cooperation

In developing their system, Cortex works mainly with pathologists, their primary source of business.

The company has two installations in Arizona. One was just recently installed at University Medical Center (UMC) here in Tucson. The other is down in Sierra Vista. Regarding the installation at UMC, Mr. Gordon provided me with the name of a cytogeneticist who is most familiar with their system - Mark Stevens. He was the head of the installation team at UMC.

Mr. Gordon is very interested in working with us as we develop our workstation. A lady by the name of Judith Krebs will be coming down to Tucson on Sept. 18 to check on the system at UMC. She is the Director of Installations for Cortex. In addition, Mr. Gordon gave me the names of two more companies whom he thinks might be interested in this and whom he is interested in working with. They are **Dianon** in Bridgeport, Conn. and **Neopath** in Seattle, WA. Dianon is very involved in information systems and also very interested in imaging. Mr. Gordon suggested trying to get a hold of their number and giving them a call. Neopath works mainly with Pap Smears. Grace Bartu is the name I was given to contact. She is working on her Ph.D. in Alzeimers and is the principle scientist at Neopath. Her number is (206) 455-5932.

Mr. Gordon requested three more copies of the letter and article initially sent to him. In addition to those, I sent him two copies of Boeckeler's preliminary data sheet and two copies of the information about Kensal which will appear on the Web. Mr. Gordon will be sending literature on their system soon.

5.1.15 Rob Deal, Antrim Corporation, Sept. 11, 1995

Antrim's pathology module is called the *Anatomic Pathology System.* It can be a stand alone system or interface to either HIS systems or LIS systems. When interfacing to LIS systems, it is usually one of Antrim's own systems. The company interfaces to all the major HIS systems, and has a total of 73 installations.

5.1.15.1 Imaging

Antrim does not currently handle images. Mr. Deal stated that their is not a big call for it by their customers (due to expected costs he thought). Though they are interested in possibly handling images down the line, it is not planned for the near future. It is something he is keeping in mind, however. If the company does eventually pick up images, they will be microscopic and gross images. Mr. Deal said that they do not work with radiology or X-rays.

5.1.15.2 Voice

Mr. Deal said that the *Anatomic Pathology System* can have voice. It can have speech recognition or speech response.

5.1.15.3 User Interface

The *Anatomic Pathology System* utilizes primarily a keyboard. They can use a touch screen, but their is not a big demand for it.

5.1.15.4 Host Computers

The platforms supported by Antrim are DEC VAX, Alpha, IBM Risk 6000, and Hewlett-Packard DHP 9000. Their microprocessors are solely Intel.

The hard drive memory is from 1GB and up, Mr. Deal speculated, and the RAM is 32 MB and up.

5.1.15.5 Cooperation

Antrim works primarily with their customer base, mainly laboratories, in the development of their systems. Since they sell their product to customers who are more stand alone, they don't work with a lot of hospitals.

Mr. Deal could not think of any AP system installations in Arizona.

In as far as working with us in the development of our system, Mr. Deal did not want to make any sort of commitment yet because it is not a focus of their immediate future. He would like to be kept updated on what we are doing however, so that if and when they decide to carry images, he can have a reference to call on.

5.1.16 Nancy Oakland, Marketing Manager of Health Sciences Systems, Sept. 25, 1995

The name of Health Sciences Systems (HSS) pathology module is *OPUS*. It can be a stand alone system if sold with the clinical package, or it can be interfaced to HIS systems. Ms. Oakland stated that as far as interfacing goes, they are HIS compliant. HSS currently has 25 installations, all in hospitals of varying size.

5.1.16.1 Imaging

OPUS does not handle images, and there are no plans for adding that feature in the near future. If and when images are implemented, Ms. Oakland did not know what kind of images they would be (i.e. microscopic, gross, or X-ray). She guessed that there was a 50-50 chance the images would being digital or analog, and she was almost certain they would be color.

Ms. Oakland also speculated that the images would be shared between pathologists. She said that if anyone wants to sell their product, they would almost have to go in that direction because that is the direction the technology of hospitals is going. The company would probably use an image file server for this purpose, and a wide area network.

5.1.16.2 Voice

The *OPUS* system will have voice. They are currently working on voice recording, voice recognition, and synthesis.

5.1.16.3 User Interface

Currently the module utilizes a keyboard, but the mouse and voice are right around the corner, Ms. Oakland said.

5.1.16.4 Host Computers

HSS supports mainly the UNIX 9000 platform, as well as their microprocessors. They do occasionally use the IBM AS/400 type.

The storage capability of their system is dependent on the hardware they link to. Ms. Oakland explained that with the UNIX HP900, you can fit 32,000 patients on it before you have to move to optical disk archiving. So their capacity is quite large.

5.1.16.5 Cooperation

HSS has worked with one large group over the past eight years in developing their system. They have developed their system for the needs of this group, and with this co-partnership, Ms. Oakland explained, their company has been able to grow into a large reference lab. Also, she is currently trying to get an agreement with the University of Florida to install their system into the Veterinary Medicine department.

They do not have any installations in Arizona, but are actively looking for one.

Ms. Oakland stated that although they are not in any position to work with us right now or in the near future, she would like to be kept updated on our progress. She will send me some literature on their pathology module for me to review. She also stated that if she could ever be of any additional help to please contact her.

5.1.17 Dr. Selig Leyser, EasyPath Software, Sept. 29, 1995

Easy Path is the name of EasyPath's pathology module. It is a stand alone system with three installations in the U.S. One of the installations is at Baylor University in Houston, Texas, while another is at the Fred Hutchison Center in Seattle, Washington (this is a center for bone marrow studies). The installations are solely databases at the moment. Though not active, the module may also have some Meditech integration.

5.1.17.1 Imaging

Easy Path can support full colored images. The kinds of images carried are microscopic (cytology and surgical), and are typically used for both reference purposes and as images for patient files. The images are digital and either color or black and white. Dr. Leyser did not know the size of the images or the number of bits per pixels. The software used to handle the images is an in-house software.

The storing capability of the module for images is unlimited for the database. Typically, Dr. Leyser said, three images per case is the standard (this can be changed). The method of indexing employed is through 4th dimension from Windows, which allows indexes to be "on" or "off." The file structure is a relational database with client servers. Dr. Leyser stated that the retrieval time of the images depends on the hardware, and he has done no testing to date to see just how long it takes. The images may be perged at any time, so storage time is determined by the user. Dr. Leyser said that the imaging part of his system is not in great use.

The images can be shared between pathologists. They would be shared over a network (EtherNet), with a hard drive storing all the data. Dr. Leyser stated that there is the possibility for CD-ROM's in the future. A local area network would be used, and the data rate is whatever the rate of EtherNet is (he did not know).

5.1.17.2 Voice

Easy Path does not have voice, but Dr. Leyser is interested in it. He is looking into a system called "Power Secretary," which would conduct voice recognition.

5.1.17.3 User Interface

Currently the pathology module utilizes a mouse and a keyboard.

5.1.17.4 Host Computers

At this time, the platforms supported by Dr. Leyser's system are solely Macintosh. He hopes to be switching to Windows 4-D in the future (a year or so). There is also the possibility of using UNIX. Microprocessors are from Motorola (they are a PC chip for the Powermac, which has a must faster speed than any others).

Dr. Leyser guestimated the memory on the Client Server to be between 3.5 and 5 megabytes, while the server could handle anywhere from 12 to 20 megabytes or more. He also stated the size of our images (25 megabytes uncompressed) would be very impractical for archiving (they would be too big for storing on anything but a CD-ROM, for example).

5.1.17.5 Cooperation

Dr. Leyser does not work with any professional societies or government agencies in the development of his system. He is a practicing physician and works off of what he knows and gathers. He does not have any installations down in Arizona.

Dr. Leyser is interested in working with us as we develop our workstation. He reiterated the fact that his system has compression, has images, and is very economical (approximately $5000.00). He also emphasized that he would be very willing to come down and put on a demonstration of his system for us.

He is sending literature for us to view.

5.2 Pathology Images From The Internet

For future comparison to images produced by Kensal Corporation, several microscopic images were viewed from various institutions with Pathology Image Databases on the Internet. Almost all of the institutions were universities who use the images for education purposes at their medical schools. Although attempts were made to contact those in charge of producing the images, no one responded. Therefore, it is not clear how these images were produced, or at what magnification they were taken at.

Images from eighteen institutions nationally and internationally were viewed. Quality, size, color, contrast and format of each were compared. Out of these 18, only two to three institutions had images whose quality was above average. Two of these institutions were Cornell University and the University of Utah. A brief description of their images follows. The other institutions had images whose quality varied. Blurriness of details was the most common problem, making the tiny structures of microscopic images hard to see. Color was a second problem, as some

institution's images had extreme colors of bright pink or red versus the regular magenta color. In other cases, the color appeared too light, washing out details. With occurrences such as these, images lack a sharp, crisp look to them that make them easy to view. Once again, knowing how these images were produced may help to gain some insight as to why these problems have occurred and how to avoid them in the future.

5.2.1 Cornell University

Cornell University has approximately 126 pathology images, both gross and microscopic, which are stored using the CompuServe GIF Format. Approximately 50 images were downloaded, focusing solely on the microscopic images. The following information was obtained from these images. The images are 8 bits per pixel (indexed color) and range in size from 122K to 179K. The average width and height in pixels is 500 x 300 respectively, and the resolution is 72 pixels/inch. Each image is titled with what the tissue is and where it is from.

Overall, the quality of these images is very good. The color and contrast are sharp, and the details are easily visible on most of the images. Of course, some images are better than others, but a majority of the ones viewed were some of the best images found. Cornell has been e-mailed to find out more about their images and to offer some insight to our future plans with imaging. No name could be found to send the message directly to, and no response has been made as of yet.

5.2.2 University of Utah

The images found on this file are probably the best I have seen so far. Utah uses these images for medical education. Their "electronic laboratory" includes more than 1500 archived images demonstrating gross and microscopic pathologic findings. The images on the file are scanned from kodachromes to make a Photo-CD, and are saved in the JPEG compressed format. They are 24 bits/pixel (RGB color), and range in size from 56K to 489K, with the latter being more common. Resolution is 72 pixels/inch, and the average width and height is 504 x 330 pixels respectively.

The images are filed under *subject areas* (11 areas total including cardiovascular, pulmonary, GI, renal, dermatopathology, hematopathology, neuropathology, forensic pediatric-perinatal, reproductive organ, and clinical pathology), *mini-tutorials* (7 total including such things as AIDS Pathology and Pathology of Drug Abuse), and *organ systems* (9 systems such as bone and joint, breast, and endocrine). The number of images under each category ranges anywhere from 5 (smallest) to 53 (largest) images.

Twelve images have been viewed mainly from the *subject areas* (two from the *mini-tutorials*). As mentioned above, they appear to be of great quality. The color and contrast are sharp, and details are very clear. All of the images seen have been obtained from autopsies.

6. NEO LENSMAN

This section briefly describes the functions and operation of the application Neo Lensman (hereafter Lensman) and a method for calibrating light. Most functions are executed from floating windows called windoids (from the 'Inside Macintosh' series describing floating tool palettes). All windoids from Lensman are illustrated.

6.1 Function Description

6.1.1 Main Floating Window Description

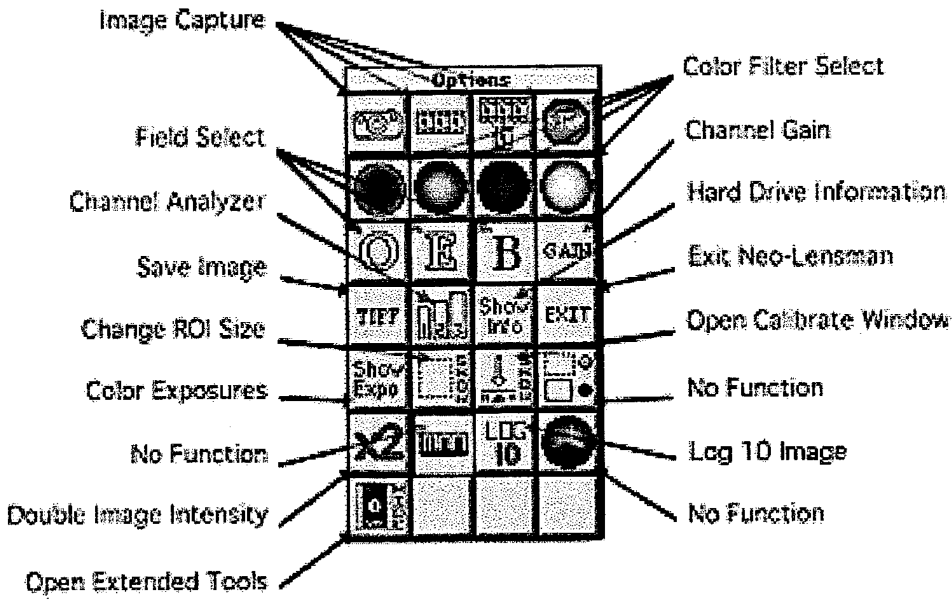
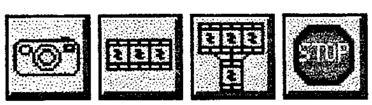
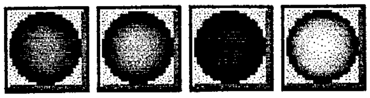


Fig. 1 - Main Floating Windoid.

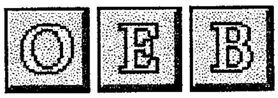
6.1.1.1  *Image Capture*

The Image Capture commands begin and end polling the camera for image data and display the results on screen. The first command takes only one picture and displays it on screen*. The second command continuously takes pictures and displays them until the "Stop" button is pressed. The third command continuously polls the camera for pictures and integrates images for improved quality. The last command, "Stop", stops polling the camera for images.

* In the latest version of Neo Lensman, the single image capture (the button with the camera icon) is not operating properly. Pressing the button seems to acquire something from the camera, but does not display an image.

6.1.1.2  *Color Filter Select*

Pressing a color button sets the camera's filter wheel to either red, green, blue, or clear. Listen for the changing filter wheel in the camera to be sure it actually has changed. A color button is always depressed (selected).

6.1.1.3  *Field Selection*

The "Odd", "Even", and "Both" commands set the software to only capture either the odd, even, or both fields of the image. To speed picture taking you can set the camera to capture either the even or odd fields only. Capturing just an odd or even field effectively halves the image vertically. To capture both fields, i.e., a full frame, the "Both" command must be set.

6.1.1.4  *Channel Gain*

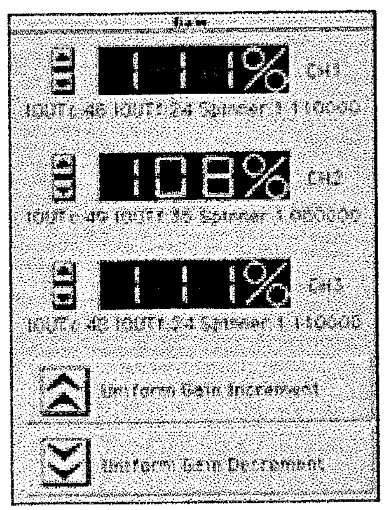
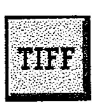


Fig. 2 - Gain Windoid.

The "Gain" function sets the gain, individually or as a whole, of the three channels. Figure 2.104 shows the "Gain" windoid with three displays with corresponding spin controls, and uniform gained increment or decrement. Clicking this button again will close this windoid.

6.1.1.5  *Save Image (TIFF)*

Opens the Apple standard dialog for saving the currently displayed image in a TIFF format. After the image is saved it can opened by any application that can read 8-bit TIFF images.

6.1.1.6  *Channel Analyzer*

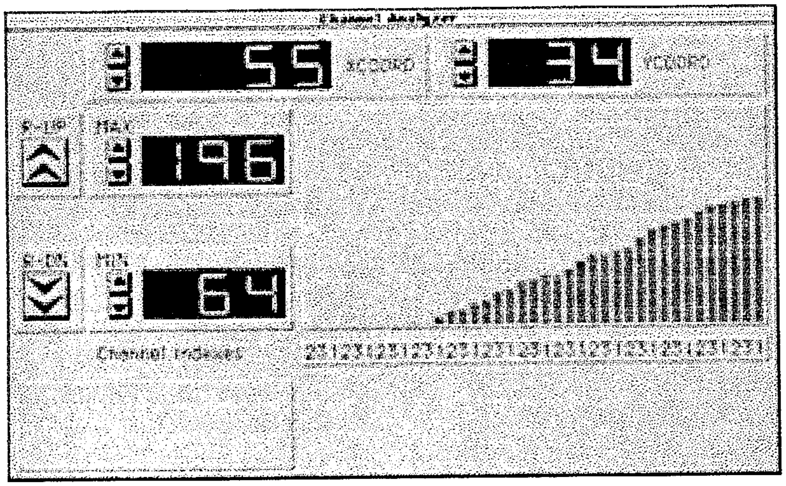


Fig. 3 - Channel Analyzer.

Within the image window is a small flashing blue line whose coordinate location is given by the displays in the upper portion of the "Channel Analyzer" windoid (here 55,34). The intensity values along this line are displayed in the "Channel Analyzer" windoid by red bars. Selecting a set of channels (red bars) will highlight them, visually emphasizing a group of channels. The upper and lower limits of the red bars are shown and altered with the left "Min" and "Max" displays. Using this windoid in conjunction with the "Gain" windoid allows the use to equalize the channels. Clicking the "Channel Analyzer" button again will close this windoid.

6.1.1.7  *Hard Drive Information*

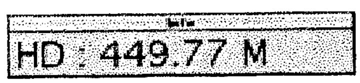


Fig. 4 - Information.

All available space (in Megabytes) on the current hard drive is displayed in this windoid. Clicking the "Show Info" button again will close this windoid.

6.1.1.8  *Exit Lensman*

Terminate the current session of Lensman.

6.1.1.9  *Display Exposure Windoid*

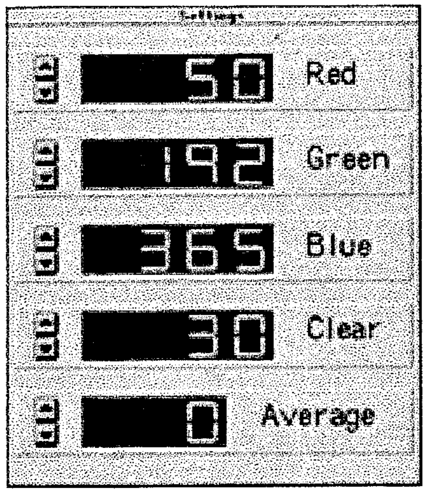
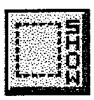


Fig. 5 - Settings Windoid.

From within the "Settings" windoid (exposed with the "Show Expo" command) the individual exposure settings for each color filter are set. Clicking the "Show Expo" button again will close this windoid.

6.1.1.10  *Alter ROI Size*

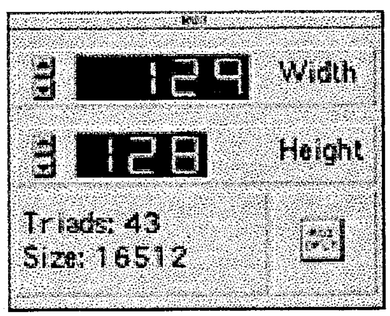
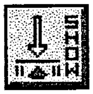


Fig. 6 - ROI Size.

Within the image window is a region outlined by a moving marquee . The region is located at the center of the image. All measurements are taken from within this region. The "ROI" windoid sets the width and height of the region. The default settings are returned with the "ROI DFLT" button in the lower right of the windoid. Clicking the "Show [Region]" button again will close this windoid.

6.1.1.11  *Display Calibration Window*

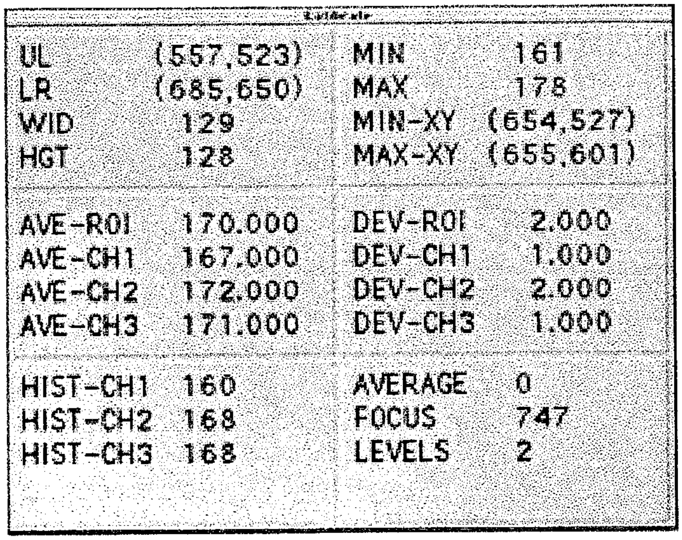


Fig. 7 - Calibration.

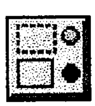
The "Calibrate" windoid lists a series of measurements. All measurements are listed in Figure 7. Clicking the "Calibrate Icon" button again will close this windoid.

6.1.1.12  *Double Intensity Values*

The "2x" command allows the user to select an already saved TIFF file (with the Apple's standard "Open" windoid") and double all pixel values. Lensman saves the changes in it's own folder with a "2_" in front of the filename.

6.1.1.13  *Log 10 Function*

The "Log 10" command allows the user to select an already saved TIFF file and perform a log operation on all pixel values. The changes are saved in Lensman's folder with a "L_" in front of the filename.

6.1.1.14    *Non-Functioning Operations*

The commands marked "No Function" in Figure 1 are reserved for future use or are not operating properly. The three open buttons at the button of the Main Floating Windoid are also reserved for future use.

6.1.1.15  *Open Extended Tools*

This command opens the extended tools under the "Test" windoid. The extended tools are listed and described in Section 6.1.2. Selecting this button again will close the extended tools.

6.1.2 Extended Tools Description

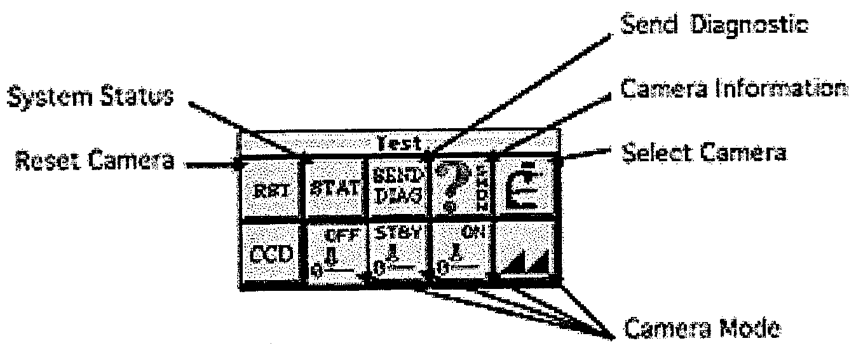


Fig. 8 - Extended Tools Windoid.

6.1.2.1  *Rest*

Resets the camera and provides the option to return all values (gain, exposure, etc.) to default values.

6.1.2.2  *System Status*

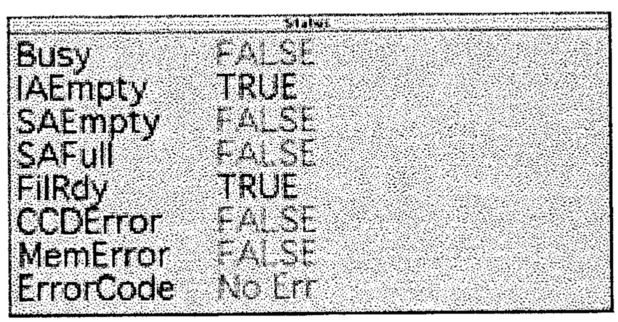


Fig. 9 - Camera Status

The "Stat" commands returns a list of Boolean values in the "Status" windoid. The list of operands are shown in Figure 9. Clicking the "Stat" button will close this windoid.

6.1.2.3 

Send Diagnostic

The "Send Diag" command sends a diagnostic operation to the camera to check for errors. The operation usually takes about two minutes to complete.

6.1.2.4 

Camera Information

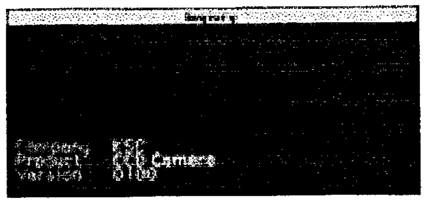
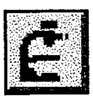


Fig. 10 - Camera Information

Figure 10 displays the "Inquiry" windoid with listed information. Clicking this button again will close the "Inquiry" windoid.

6.1.2.5  *SCSI Camera Select*

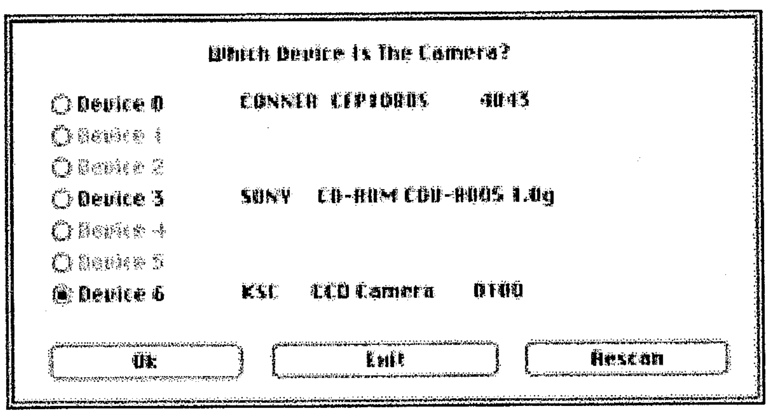
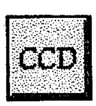
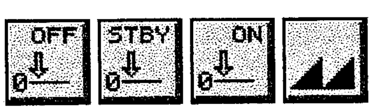


Fig. 11 - Camera Select

This command displays a dialog asking the user to select the camera. All seven [available] SCSI devices are shown. Clicking "OK" sets the current selection. "Exit" will exit Lensman. "Rescan" will scan the SCSI bus again.

6.1.2.6 

Unknown

6.1.2.7 

Camera mode

6.2 Menu Commands

6.2.1 About Neo Lensman (under "Apple" menu)

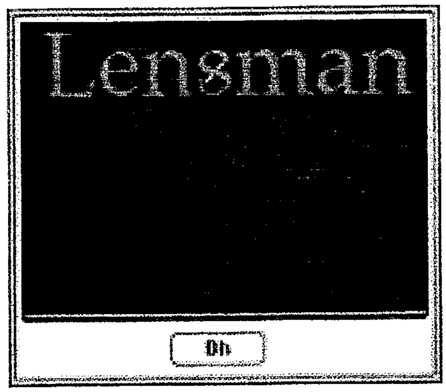


Fig. 12 - About Lensman

The "About Neo Lensman" command opens a dialog box describing Kensal. Clicking the "Oh" button closes the dialog.

6.2.2 Quit (under "File")

Exit Neo Lensman

APPENDIX A
RECOMMENDED LIGHT CALIBRATION

What follows is the recommended method for calibrating light on the microscope and within Lensman:

1. Insert slide and move to clear glass.
2. Set the desired Objective (this process must done for each objective) and focus visually.
3. Set the microscope slider to 7.
4. In Lensman, set the filter to RED.
5. Open the "Calibration" and "Exposure" windoids.
6. Begin polling the camera continuously.
7. Adjust the microscope field stop until the "circle" is just outside of the captured image.
8. Adjust the RED exposure in the "Exposure windoid until all "Hist Chn"'s in the "Calibration" windoid reach the value of 120. DO NOT adjust the microscope's light slider.
9. Switch to the GREEN filter.
10. Adjust the GREEN exposure in the "Exposure" windoid until all "Hist Chn"'s in the "Calibration" windoid reach the value of 120. DO NOT adjust the microscope's light slider.
11. Switch to the BLUE filter.
12. Adjust the BLUE exposure in the "Exposure" windoid until all "Hist Chn"'s in the "Calibration" windoid reach the value of 120. DO NOT adjust the microscope's light slider.
13. Close the "Exposure" window.
14. Make sure the "Calibration" window is still open.
15. With light calibrated, move to a desired location.
16. Set the filter to GREEN
17. Focus visually through the oculars.
18. With the camera continuously acquiring images, focus the image on screen.
19. Now focus the microscope stage until the "Focus" number, in the "Calibration" windoid, peaks.
20. The camera in now focused for this location. Each time stage location changes (especially at higher magnifications), refocus the camera.
21. To end polling the camera continuously select the "Stop" button.

With the camera calibrated for the current objective, and focused for the current location, three images can be acquired to create a color image:

1. Begin polling the camera continuously.
1. Set the filter to RED while continuously acquiring images.
2. After a RED image is display, select the "TIFF" button to save the image to disk.
3. Set the camera to the GREEN filter while still capturing image continuously.
4. After a GREEN image is displayed, save to disk with the "TIFF" button
5. Set the camera to the BLUE filter, and after an image is acquired, save to disk.
6. In another application, such as Adobe Photocopy, these three images can be combined to create a 24-bit color image.

7. SOFTWARE FOR POWERMAC (by Gregory Guerin)

Kensal Corporation's Triakis program contains a software morphology engine written in 68000 assembly language. It was my goal to convert this to run on the PowerPC-based Macintosh, and benchmark its speed. The strategy I chose was to convert the 68000 assembly language into a high-level C form, compile that C code for the PowerPC, then evaluate the resulting code, both for actual speed and overall quality of compiler translation. Other Triakis functions written in 68000 assembly language and converted to run on the PowerPC-based Macintosh and benchmarked for speed are the workspace booleans operations, boundary-setting and volume operations, and the encoding of a gray-scale image into a workspace solid.

To make the conversion process more tractable, Kensal representatives agreed that only the "mode 0" portion of the assembly-language engine would be converted for the initial benchmarks. Since this was believed to make up over 99% of all current uses of Triakis, it was deemed to cover most existing customer uses.

After analysis and conversion of the 68000 assembly language into a C version, the new C code would be validated first on a 68000-based Macintosh, before recompiling for the PowerPC. The C engine's output would be compared byte-for-byte with the output of the known-working 68000 assembly-language engine, after feeding identical inputs to both routines. If both the C-code and the assembly-code routines produced identical output for a variety of identical inputs, then we could conclude with a fair degree of certainty that the new C code was correct. It could then be recompiled for PowerPC and benchmarked for speed and C-compiler code quality.

7.1 Validation Results

These results are in the file "=PowerTest (68K).out.68K". The program (included in package) that produced this file contains working versions of both C and 68000 assembly-langauge versions of the morphology engine. The assembly-language was taking verbatim from source code supplied by Kensal Corp, with minor editing done to make a C-function prolog and epilog so that a proper C stack-frame was correctly set up. As a further check, the actual executable code was disassembled from the new program, and compared with a disassembly of known-working code from a Triakis test-facility program. Since the code matched, it was deemed correct in its new assembly-language form.

The C code was written so as to improve PowerPC execution time, not necessarily optimal 68000 execution. In particular, some idiomatic expressions C tend to produce sub-optimal PowerPC code, so these were avoided in favor of generally simpler expressions, or expressions which did not depend on just-calculated results, thereby exploiting the PowerPC's super-scalar pipelined architecture. By far the best use of PowerPC resources is to have the C code arranged so that everything can be placed into PowerPC registers. This technique quickly exhausts the available 68000 registers, but we were not trying to create the best C-code for the 68000, merely a correct and verifiable representation that would produce good PowerPC code.

The test-bed program (known as "PowerTest") created for this exercise performs some trivial transformations on mechanically generated data. The data for the required look-up table (LUT), shift-table, and mask-table were determined by substituting a "dump-to-file" replacement routine into Kensal Corp's existing Triakis test-program. This data made sense, once it was seen, so it was used to create "test-tables" for the PowerTest program.

The PowerTest program runs the two morphology engines (C and 68000 assembler) over several input data sets designed to exercise the main data-dependent pathways of the engine routines. It then performs a byte-for-byte comparison of the output of these two routines, and

emits a unique message if it detects a difference. It performs these tests over various sizes of data sets, representing typical ranges of user data.

The morphology engine itself is written in such a way that certain commonly occuring data patterns are recognized quickly, then handled trivially. All other data patterns are handled by the slower but fully generalized part of the engine. The two "trivial cases" are patterns of all 0-bits and all 1-bits. All other bit-patterns are passed to the general-purpose portion of the engine. These three pathways are the primary data paths through the engine. After this initial 3-way decision, a single intermediate value is produced, which is then handled in a uniform manner to generate an output value. Hence, if we generate input data that matches each of the "trivial" cases, as well as the "everything else" case, we can expect to exercise all relevant pathways in the engine. Furthermore, if we observe differences in output between the known-good 68000 assembly-language engine and the C engine, we can narrow down the scope of where the error might be by observing those patterns that fail.

The C engine validated perfectly when subjected to input patterns of all 0-bits, all 1-bits, and alternating bits (hex 55). It also validated other test patterns fed to it, including count-down patterns, and count-down with mask patterns. These patterns were validated for data sets consisting of cubes having edge lengths of 64, 96, 128, 192, and 256 voxels. All data matched perfectly between the C and assembly-language engines.

A side effect of this validation process is that we can see the relative speeds of the C and assembly-language engines. Running on a 68040 (40 MHz, Quadra 840AV), the assembly-language engine is consistently faster than the C engine, by about 30%. That is, the assembly-language engine takes only about 70% of the elapsed time of the C engine. This varies slightly depending on the data, but not by much.

7.2 Interpreting the Results Files

Each result file is the output of a complete run of one of the test programs: PowerTest for 68K or PowerTest for PPC. Each test run feeds various test data through different sizes of cubic data sets, measures and displays the elapsed time for ONLY the engine-processing phase, and then moves on to the next data set or size. That is, the time to allocate or fill in the test data, or any other overhead beyond actually running the morphology engines is NOT included in any displays of elapsed times.

The C code determines (through compile-time conditionals) whether it is 68000 code or PowerPC code, and whether it was the CodeWarrior or MPW C compiler. (During development, the MPW C compiler was used as a validity check against the CodeWarrior compiler. The MPW results are not included here, since they are not relevant to the PowerPC benchmarks.)

At run-time, the code also determines the machine ID, and both the virtual and native CPU identifiers. This information appears at the top of each cube-size series of tests. Machine ID 78 is a Quadra 840AV, run by a 40 MHz 68040 CPU, which has 4K of on-chip code cache and 4K of separate on-chip data cache. Machine ID 65 is a Power Mac 8100/80, run by an 80 MHz PowerPC 601 CPU, which has 32K of unified (code+data) on-chip cache, and 256K of off-chip level-2 cache. The Power Mac has a "virtual CPU" of a 68020 without an FPU, which is the CPU model for "emulated" software (hence Apple's designation of a "68LC040 emulation" isn't exactly true, but is not relevant here, so will not be discussed further, except to note that the emulated 68000 code ran about 3 times slower than the Quadra 840AV).

After the information about the machine is displayed, a summary of the cubic data sets is displayed. This is primarily debugger-level information, but it is interesting to see the "perCube" value increase to a healthy 2M for the 256-edge size.

The first calls to the engine routines are to make sure that the Mac's on-demand code-loading process has loaded the routines into memory, so we are not benchmarking disk-read times.

The first three tests are run on a single plane of the cube, as a quick validity check. The term "solid-fill" means that the input data-set is filled completely with the given 32-bit pattern. Later, a "masked-fill" test is done, in which a constantly decrementing counter is masked with the given pattern, and that changing value is used to fill the data-sets. "Masked-fill" tends to produce data-sets with fewer set bits, thus more closely reflecting the nature of actual data.

Since only one plane of data is transformed for the first tests, the elapsed times are not especially representative. The one thing to note is the absence of any messages expressing a difference between the output data-sets.

The next three tests are solid-fill tests over the entire cube of data. These are the speed benchmarks of primary interest. The "all 0's" pattern is trivial case #1. The "all 1's" pattern is trivial case #2. The "$55" pattern is alternating 1's and 0's, and hence always takes the general-purpose pathway through the engine. These three tests demonstrate the expected best-case (all 0's) and worst-case (all $55's) performance. Typical performance will lie somewhere in between.

The last four tests for a given cube-size are intended to show "typical case" performance. They are all "masked-fill" patterns, which means that the given mask is ANDed with a 32-bit down-counter value, and the resulting 32-bit pattern is written to the data-set. The entire data-set is filled in this way. The down-counter starts at a count representing the number of 32-bit values in the overall data-set. So, a 32K data-set would start its counter at 32K/4 or 8192. By varying the mask-value, we can produce data-sets with fewer or greater numbers of varying bits in the pattern.

The mask-value of 0 effectively clears all the down-counter bits, so the pattern is identical to a solid-fill pattern of 0, and we observe that the execution times are the same as for the earlier test of just such a pattern. The mask-value of all 1's does nothing to the down-counter, so it produces the most varying pattern of data. The mask-value of all $55's effectively clears alternating counter bits, so the result varies at about half the rate of the all 1's pattern. The mask-value of $4F produces data with a varying 4-bit pattern in the LS bits, occasionally toggling the bit in the $40 position of the mask. This produces a pattern with 3 bytes of 0's for every byte containing any 1 bits, and probably represents a typical sparse data set. You can observe that the times for each of these mask-filled patterns lies between the above-noted best-case and worst-case performance. You can further observe that the C engine is consistently slower than the 68000 assembly-language engine.

7.3 PowerPC Benchmark Results

These results are in the file "=PowerTest (PPC).out.PPC". They were run on a Power Mac 8100/80, and executed as native PowerPC code. The story is most clearly seen in the run-times of the 256-per-edge cube, compared to the 68000 run for the same cube size. The PowerPC C engine is consistently 3 times faster than the 68000 assembly-language engine running on the Quadra 840AV (which is the fastest 68K-based Mac made). In the case of "all 0's", the performance gap is wider still, about 3.33 times faster than the 840AV. The gap between the C engine on the PowerPC and the C engine on the 840AV the is always well in excess of 4 times faster in favor of the PowerPC.

A key thing to note in these results is the appearance of the "unmatched" messages after each test run other than all 0's. These arise because there is no simple way to call emulated 68000 code from a PowerPC native program (or vice versa). The simplest method for writing code is either all PowerPC or all 68K. Since we had already validated the C engine using the 68K-based

Macintosh, it was redundant to validate it on the PowerPC. So, the simplest way to compile for PowerPC was to define an empty function named "PlaneProcess_68K", which appeared instead of the actual 68000 assembly-language function when compiled for PowerPC. This was all controlled by conditional compilation that detected predefined compiler symbols, and automatically selected the appropriate code for compilation. The reason why we don't see the message for the "all 0's" case is that the output data-area is cleared to 0's before the transform test is run, so if nothing runs, it will compare 0's with 0's and always match.

7.4 PowerPC Code Quality

The CodeWarrior C compiler for PowerPC recognizes the large register-set of the PowerPC CPU, and exploits it with reasonably efficient code generation. The assembly language produced by the compiler is shown in "PPC asm". While it might be possible to somewhat improve this code by manually recoding in PowerPC assembly language, it is very unlikely that any improvement beyond 5% or so would be possible, and that 5% would be hard-won indeed. Conveniently, the high-level C code can be written so that it maps fairly well one-to-one to PowerPC instructions. Although this eschews certain idiomatic C expressions such as "*pp++", it can have a substantial impact on the nature of the generated code. Somewhat unexpectedly, what might appear to be "inefficient C" actually generates very good PowerPC code, because it exploits both the nature of the PowerPC instructions (3-operands), and the parallelism of the CPU. So "good code" is actually a series of expressions that has LITTLE dependence on immediately preceding calculations, and "bad code" is a series of expressions in which the just-calculated values are immediately used in following expressions.

Instruction ordering to reduce scheduling delays in the generated code is about as good as it can get. In the end, the primary difficulty in exploiting even more parallelism of the PowerPC is the inherently sequential nature of the algorithm, in which calculated values are fed through a steadily narrowing funnel of operations, eventually terminating in a single result.

7.5 Summary

The C version of the software morphology engine runs about 3 times faster on an 80 MHz PowerPC than the equivalent hand-optimized 68000 assembly-language runs on a 40 MHz 68040. Although once considered "top-of-the-line", an 80 MHz PowerPC is now considered "about average" in Apple's range of PowerPC Mac offerings, and 120-132 MHz is now the high-end. On the other hand the 40 MHz 68040 of the Quadra 840AV has never been matched or exceeded in any other Macintosh. Although there are several 33 MHz 68040 machines, these can be expected to run about 20% slower than the 840AV.

In a sentence, then, an "average" Power Mac will run the software morphology engine about 3 times faster than the fastest 68040-based Mac ever made. Further, writing the engine in C has no significant impact on performance, since the compiler-generated code is fairly well optimized, given the nature of the algorithm.

7.6 Workspace Booleans

These were very straightforward to recode in C, and equally straightforward to test. Trivial C implementations were written, which operated solely at a byte level. Although simple, these routines suffer enormous speed penalties. Hence, the final routines were written to exploit both 32-bit PowerPC data sizes, as well as loop unrolling.

In my experience, unrolling loops by a factor of 4 usually garners the majority of all unrolled-loop speed benefits. Increasing to 8-level unrolls is rarely worth the effort, or the code

size or complexity. Coupling a 4-level loop unroll with 32-bit data size means that each loop iteration would operate on 16 bytes of data at a time. This seemed to be sufficient.

Since the workspace length is specified as a byte-count, up to 15 extra bytes may also need to be operated upon. These were done using a simple byte-oriented loop, after the main loop had run.

The output of the optimized loops was compared byte-for-byte with the trivial version's output, to verify that no coding errors had been made. The optimized loops easily out-performed the trivial byte-oriented versions, with no differences in output ever observed.

7.7 Boundary-Setting

Triakis often needs to set or clear all the voxels that occupy the faces of a workspace, and it needs to do this quickly.

The basic strategy was to fill one plane completely, then to work serially through the other planes, filling the "side" lines rapidly, then moving through each "line end" pair of bytes. The final plane would then be filled completely. This strategy was deemed to make the best use of the PPC's data cache, since this method would always work through in ascending order of address, never revisiting any areas of memory.

The resulting C code was verified by breaking into the debugger and inspecting the data. All data sizes tested worked perfectly. The performance was very good, even with large workspaces.

The boundary-setting routines were further tested as part of the volume-calculation tests, the next modules converted.

7.8 Volume Calculations

Calculating the volume of a workspace (the number of ON voxels) requires examining every byte in the workspace. This was done by reading a 32-bit value from the workspace, translating it through a "count table" in 8-bit chunks, and summing the resulting values. This was the technique already used by the 680x0 assembly language, but extended to the 32-bit values most efficiently handled by the PPC.

This routine was tested by filling workspaces with all 0's, all 1's, and alternating bits, each time calling the volume calculator. Since the dimensions of the workspace were known, the correct results were trivial to verify.

Additional tests were conducted by calling the boundary-setting routines on the above-listed fill-patterns, and verifying that all the results were as expected. They were.

7.9 Gray-Scale Image Encoding

A gray-scale image can be converted into a solid in a workspace by interpreting gray-levels as "column heights", and filling the space accordingly.

The C routine used the same basic method as the 680x0 routine, with one minor change: removing all multiplies and divides outside the main encoding loop. This was accomplished by recasting the necessary calculations in a fixed-point format that maintained full precision, yet could easily be converted to pure integer form with nothing but shifting. The resulting threshold levels

were then validated by actual comparison with the original calculation, and no discrepancies were found. Thus, the validity of the new calculations was determined.

The basic method of encoding was identical to the 680x0 method, where gray-scale bytes are compared in groups of 8 with the threshold, to construct a single-byte value to be placed into the workspace. The speed of this method was more than enough to encode a 128 x 128 gray-scale gradient into a 128 x 128 x 128 workspace in 183 mS on an 80 MHz 601. From this result, encoding into a 128 x 128 x 64 workspace should take half as long, or about 92 mS, which is well under the constraint of 250 mS initially laid down. The performance should be correspondingly higher on faster 601's, or on 604's.

7.10 Comments

The byte-oriented booleans are astoundingly slow on the PowerPC. Although I have no explanation for this, it may be a combination of poor pipelining, poor cache performance, and other factors. However, since these routines were used only to verify the others, they have no impact on the final product.

All C routines have been tested and validated on a 68040 machine. In some cases, their speed is very close to the assembly-language originals, but in other cases the difference is 40% or more. This is not surprising. However, the performance and portability should make it simpler to integrate these new functions during the porting to PowerPC.

The CodeWarrior C compiler was used for development, then the Symantec C (v 8.0) compiler was used for final testing and tuning. No portability problems were encountered at all, but the speed of Symantec C's code was invariably below that of CodeWarrior. Even Symantec's "most optimized" code never exceeded even barely optimized code from CodeWarrior. With instruction scheduling enabled in CodeWarrior (not even a Symantec option), the speed difference increased even more.

Sometimes the speed differences were insignificant, although they were always visible. For example, the booleans tested at nearly identical speed: 263 mS for Symantec vs. 256 mS for CodeWarrior, a difference below 3%.

In one or two cases, the differences were more substantial. For example, the Encode test was 183 mS for Symantec and 149 mS for CodeWarrior, or almost 20%. Also, the FindVolume tests for Symantec C averaged to about 23.7 mS for a 128 x 128 x 128 workspace, while CodeWarrior came in at about 17.1 mS for identical data, nearly 30% faster.

It is quite clear that the quality of CodeWarrior's code generation is substantially better than Symantec's, especially for non-trivial code. Also note that CodeWarrior produces slightly smaller code, although these differences were always well under 10%, and would probably change if Symantec simply generated faster code.

7.11 Included Files and Programs

=PowerTest (68K) — 68K-version of test-bed program (run it and see)
=PowerTest (68K).out.68K — results of run on Quadara 840AV
=PowerTest (PPC) — PowerPC-native test-bed program (run this one, too)
=PowerTest (PPC).out.PPC — results of run on Power Mac 8100/80
PPC asm — PowerPC code generated by CodeWarrior C compiler
PPC C — portion of C code that generated "PPC asm"

8. FORTY MHZ TC217 CCD CAMERA (by Greg Kline)

The TC217 CCD manufactured by TI is a 1154 by 488 pixel frame transfer CCD with on board frame memory. There are three video output channels each outputting a pixel 180 deg. apart from the other. By employing a transfer method called centroid shift during altering frame readouts a resolution of 1154 x 972 can be achieved. For the rest of this report assume a resolution of 1154 x 972 is used. The TI data sheet for the TC217 spec.'s a max. pixel rate per channel of 7.2MHz or a over all pixel rate of 21.6MHz at this speed a frame rate of only 15fps max. can be achieved. The purpose of this project is to design, build and test a 40MHz serial driver (individual channel pixel rate of 13.333MHz) and confirm by the use of a scope valid pixel shape for digitizing later and good light sensitivity during exposures.

8.1 Circuit Description

Refer to schematics test circuit for 14MHz srg's (Figure 8-1). U4 the TC217 is being driven during the parallel transfer period by standard TI drivers U3 and U6. The parallel transfer period timing does not change.

The new serial signals (SRGS and TRG) are derived from Ken Crocker's timing of U1 alteras EPM7128-10 (Figure 8-2) all timing is based on a 80MHz master clock, parallel timing periods are normal 1.2MHz and 3.2MHz. The three SRGS are 13.3MHz each for a 40MHz pixel rate, TRG although a serial signal it is only active during the horizontal time period for three pulses at 3.2MHz. The SRGS and TRGsignals drive SILICONIX TP06101 P-CHANEL enhancement mode MOS transistors with rDS on of 10ohm and a Vgs of -2.4V the schematic shows the prototype wiring but during testing I discovered the 15pf gate capacitance of the TP0610L was a little much for a single I/O pin of the EMP7128-10 (capable of sourcing 5ma) in future versions 2 I/O pins in parallel will be used this will insure fast rise times through TP0610L. For this prototype a 74AC541 octal driver was installed (not shown on schematic).

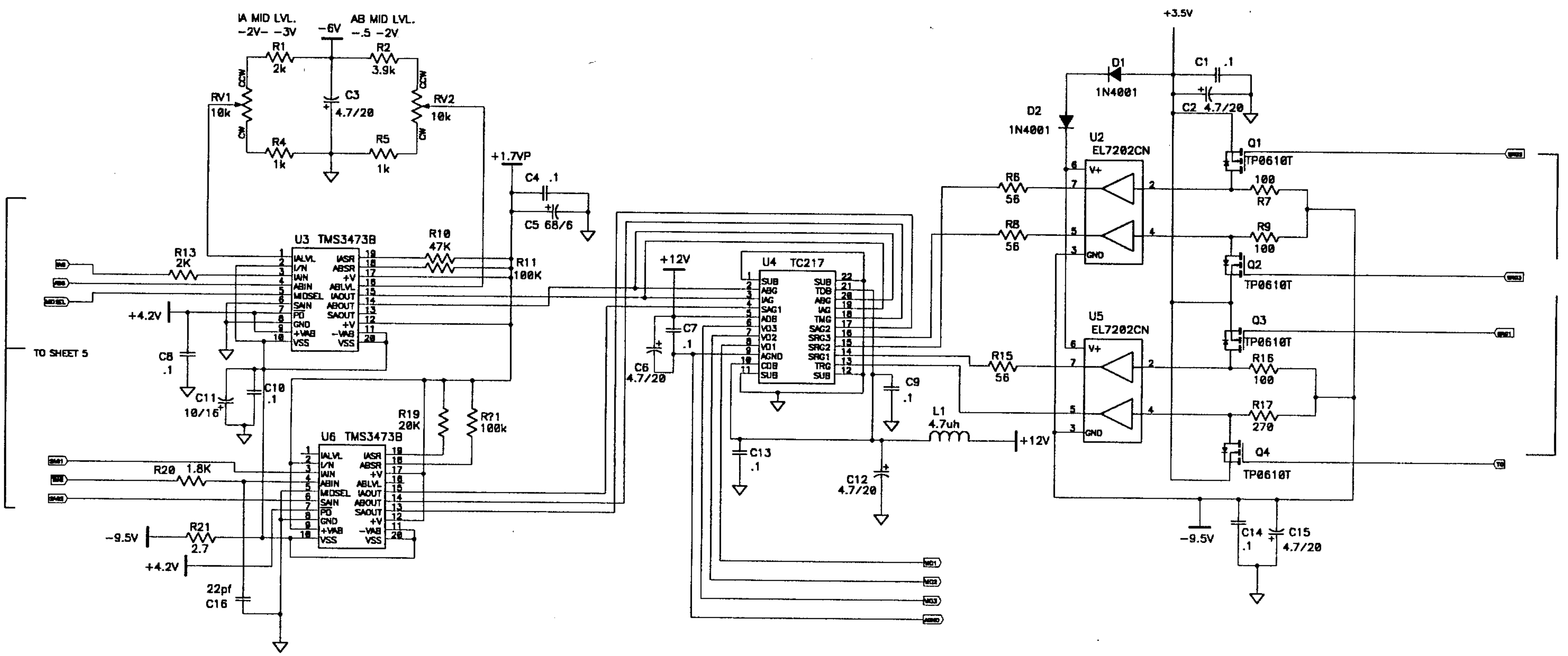
Q1 - Q4 are operating at +3.5V and -9.5V with peak currents of 118ma and a 1 third duty cycle so a SOT23 packages will be no problem for actual PC boards. The 0 to 5V signals from U1 are inverted and translated to +2 to -9.5V to drive

U2 and U5 ELANTEC EL7202 high speed mosfet drivers capable of delivering peak currents of 2A into high capacitive loads. U2 and U5 are operating at +2V and -9.5V. SRG1, SRG2 and SRG3 then drive through 56 ohm resisters into the CCD. the input capacitance of the SRGS is a max. of 180pf on this CCD I estimate 120pf of input capacitance therefore R6,8,15 were selected to reduce overshoot and undershoot and to achieve a good crossover point between SRG1, 2 and 3 at SRG inputs to CCD as shown in Figure 8-4. Both U2 and U5 are dip packages, U5 is fine in terms of power dissipation its driving only SRG1 at 1 third duty cycle TRG is very small only three pulses during the horizontal interval. but U2 is driving both SRG2 and SRG3 at total duty cycle of 2 thirds getting close to 700mw although in spec the next revision will break up U2 into to packages paving the way for using 650mw SO8 packages.

8.2 Conclusion

Driving the TC217 CCD at a serial register rate 13.33MHz per channel and an over all pixel rate of 40MHz will work. It will provide a sampling area of about 9ns to14ns of valid video.

Figures 8-3 through 8-6 show the SRGS and video output signals at normal speeds of 7.2MHz and then at 13.3MHz.



UNLESS OTHERWISE SPECIFIED ALL RESISTORS 1/4 WATT 5% ALL CAPACITORS IN uf NOTES:	KResearch	Company KENSAL CORPORATION	
	Title TEST CIRCUIT FOR 14MHZ SRG'S		Sch REV PCB REV
	Date 6/9/95	PCB NAME	
Desc.	SCH. NAME 40MHZDRV.SCH	SHEET 1 OF 2	

Fig. 8-1 - Schematics test circuit for 14MHz srg's.

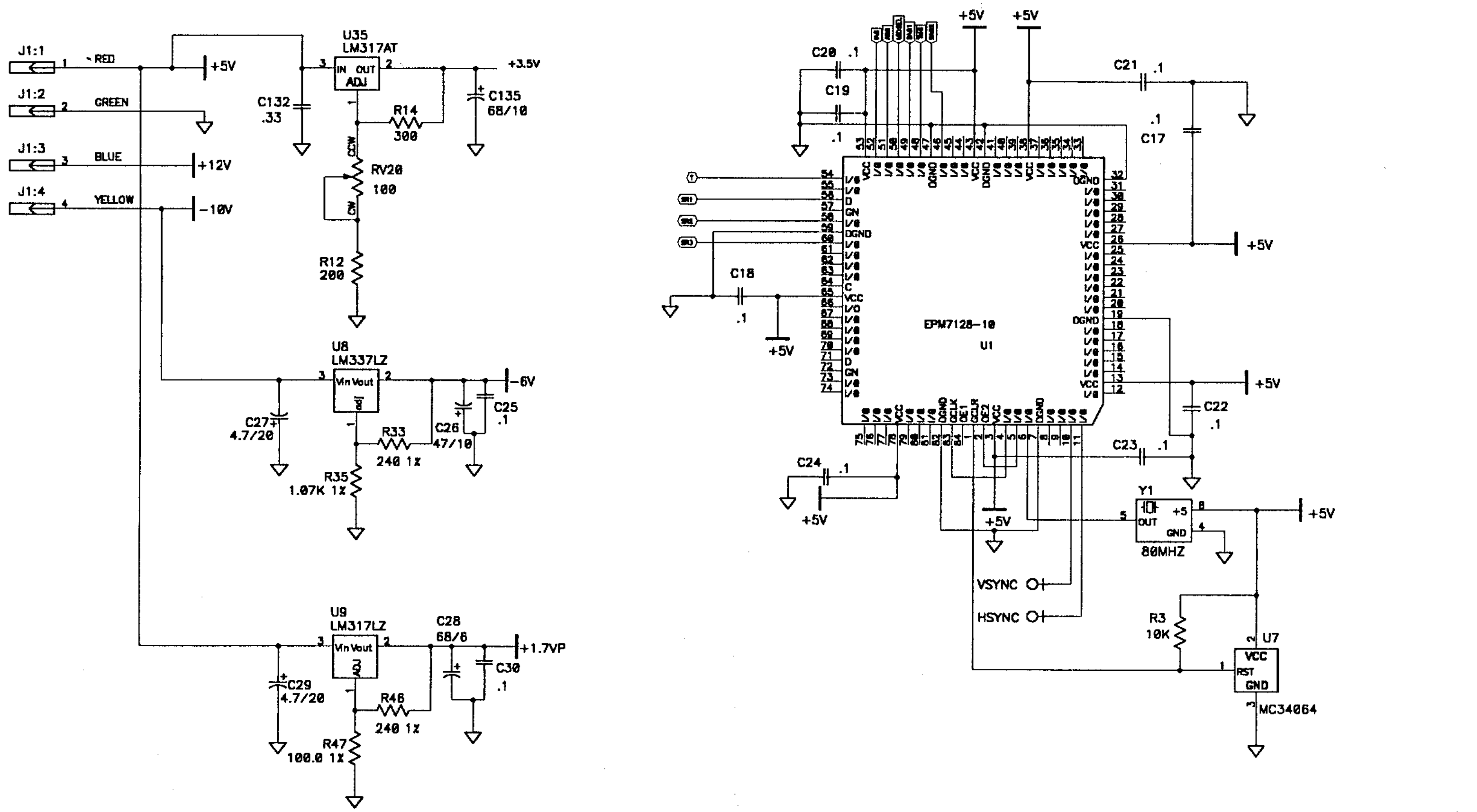


Fig. 8-2 - Timing of U1 alteras EPM7128-10.

UNLESS OTHERWISE SPECIFIED	KResearch	Company	KENSAL CORPORATION
ALL RESISTORS 1/4 WATT 5% ALL CAPACITORS IN uf	Title 40MHZ TIMMING AND REGULATORS		Sch REV
NOTES:			PCB REV
	Date 6/6/95	PCB NAME	
	SCH. NAME 40MHZDRV.SCH	SHEET 2	OF 2
Desc. TEST CIRCUIT FOR 14MHZ SRG'S			

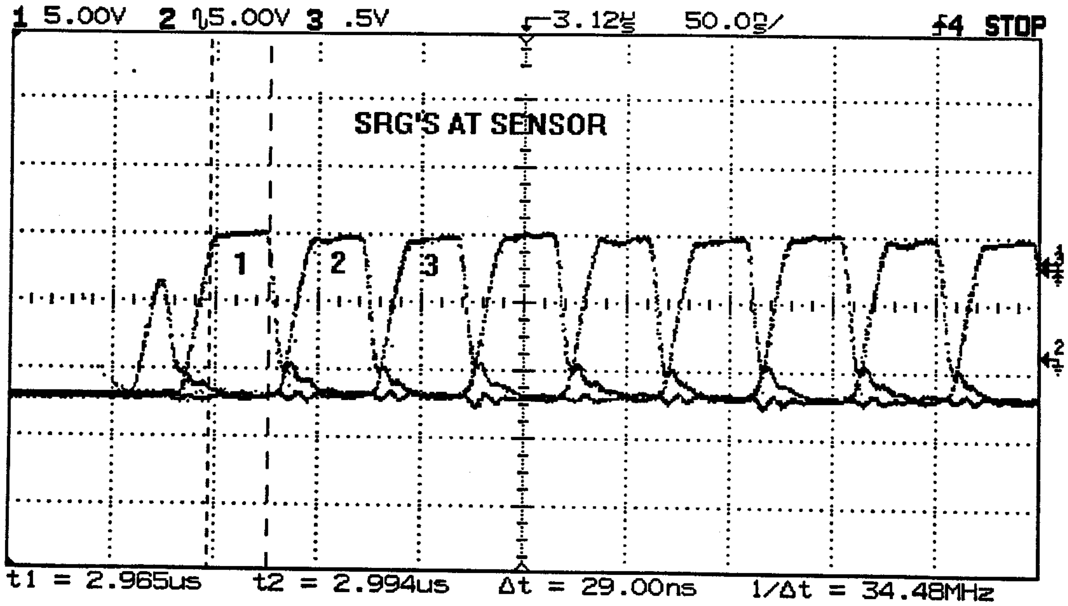


Fig. 8.3 - SRGS at normal pixel rate of 7.2MHz per channel.

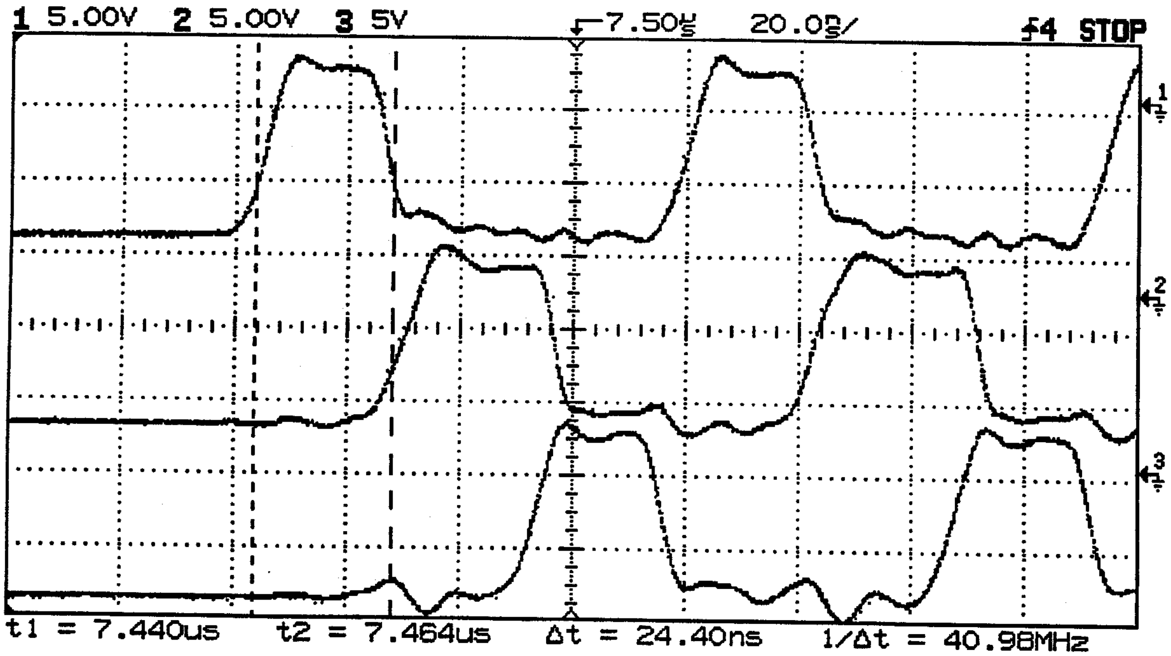


Fig. 8.4 - SRGS at CCD 13.3MHz.

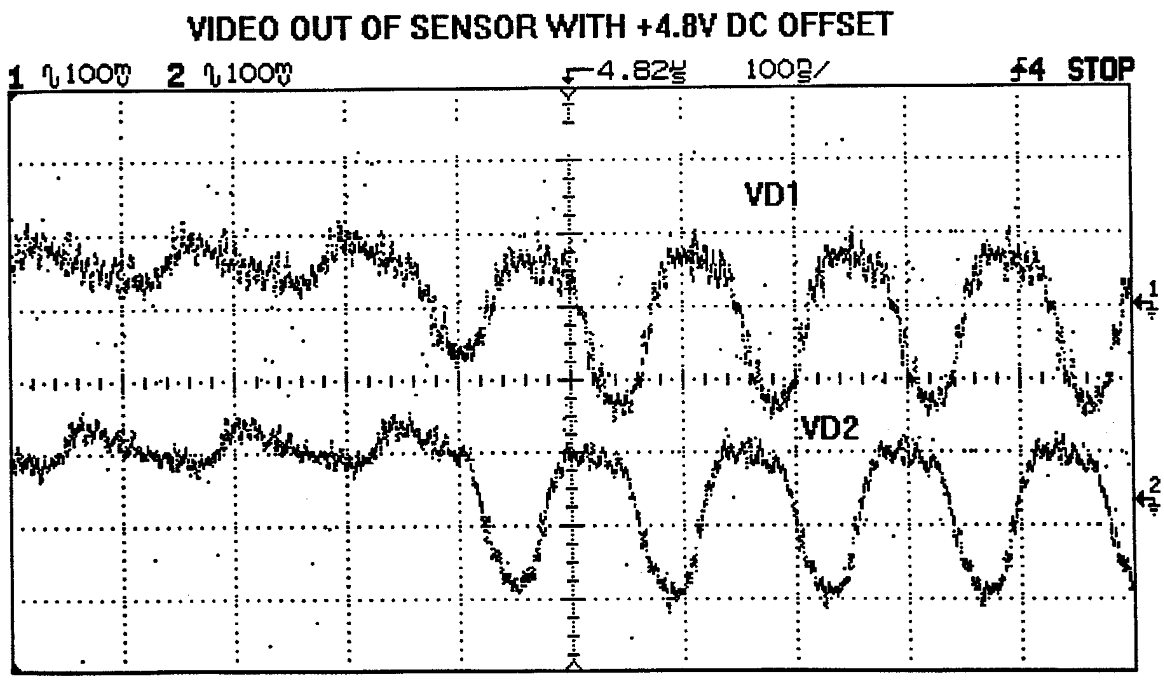


Fig. 8.5 - Normal video out of CCD at 7.2MHz.

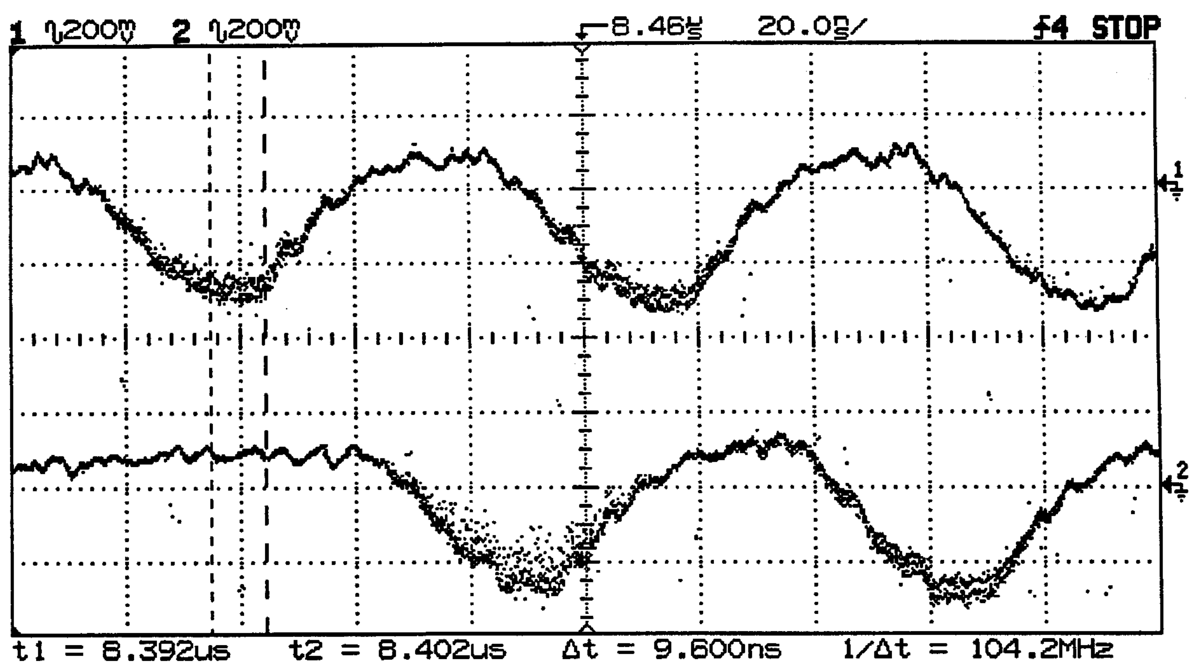


Fig. 8.6 - Video out at 13.3MHz.

9. CONCLUSIONS

This is the final section of our first Annual Report to the U.S. Army Medical Acquisition Activity (Ft. Detrick, MD). It provides four subsections that relate directly to the four areas of activity outlined in Section 1. Recommendations for work to be completed during the second year of our research and development study are given as appropriate.

9.1 Working Environment

The worst mistake that the research and development engineer can make is to be unfamiliar with the environment in which the system he/she is designing must operate. Since PCM (PC Microscope) is an advanced instrument whose use in anatomic pathology is a total departure from all previous microscopes, it was essential that we work with anatomic pathologists (both military and civilian) in order to obtain detailed reactions to our concept. This was done by extensive meetings with the pathology community as reported in Section 2. We found that the majority of pathologists are still apprehensive about computers and their deployment in pathology imaging. (This is totally different from the radiology community where the computer has been an accepted tool since the introduction of computer aided tomography.) Thus conflicting comments were received. The more computer-experienced pathologist accepted our ideas readily, whereas the "old guard" felt that there was no place for computer imaging in the pathology laboratory. Many ideas were advanced concerning the method of viewing human tissue samples at various magnifications using PCM. Our conclusion was that the negative reaction of some pathologists to video display was due to the fact that presently NTSC video is employed yielding a small, low-resolution image. PCM will circumvent this by using HDTV (High Definition Television). This results in an image that encompasses four times the area normally observed under NTSC and where the resolution of the display matches the resolution of the microscope optics.

Furthermore, PCM will use "lensless scanning" to form an image of the full coverslip - a task that cannot be performed by any known microscope system due to the limitations of physical optics. This feat is achieved by the fiber-optic-coubled LSDA (Line Scan Diode Array) furnished by EG&G Reticon (Sunnyvale, CA) with whom we have been working since 1992 when lensless imagery was first demonstrated. The reaction of pathologists to the lensless images that Kensal were able to produce was extremely positive. Some pathologists could even <u>diagnose</u> from the lensless image without using high-resolution except as a confirmation tool.

<u>Future plans</u> will cause the focus of our work on the medical pathology environment to be limited in year 2 to an interaction between the pathology staff at the Luke Air Force Base hospital and Mayo Clinic (both in Arizona) as soon as the Boeckeler prototypes are installed at those two locations and are in operation in a telemedicine network. In this mode either Luke or Mayo will transmit a lensless image from one to the other and the recipient will ask the sender to produce high-resolution pictures of certain areas marked electronically on the lensless image. These high-resolution images will be sent back over the ISDN data link to the requester. Next, the requester will perform his/her diagnosis. This will be the prime future effort in our program for Ft. Detrick and will dominate year two so far as <u>interaction with the working environment</u> is concerned.

9.2 Hardware Design and Fabrication

Preliminary investigations that were successfully conducted with the TC217 video "chip" will be translated in year 2 into a full-fledged design and fabrication effort of a preliminary prototype of PCM (to be followed in year 3 by the fabrication of several of these prototypes). The year 3 effort will be done in conjunction with Loral (San Jose, CA) who are the prime contractors of the major military hospital effort in imaging (called MDIS - Medical Diagnostic Imaging System). MDIS is primarily concerned with radiological imaging and is installed at major military medical hospitals throughout the USA with installations planned in Hawaii and South Korea.

Loral has agreed to work with Kensal staff in providing hardware (if required) and consulting advice that will assist Kensal staff in designing PCM in such a way that it may be interfaced with MDIS during year 3. Since experienced video electronic engineers who are willing to work at a small business such as Kensal are hard to find in Arizona, Kensal staff will contract out a great deal of this work to organizations in California where such talent is readily available.

Future plans, therefore, are to have Kline Research (Reseda) build the video imaging system (both CCD and LSDA). Ken Crocker Consulting (San Diego) will build two interface cards to the Apple Macintosh host (9500/120) for the purposes of (1) moving the mechanical system that controls the position of the microscope slide and (2) "captures" the video produced by the Kline Research cameras. After investigating possible collaborators in Arizona, we , again, have elected to go to California (as recommended by Boeckeler Instruments, Inc.) and contract with Optical Systems Corp. (Valencia) for the mechanics and optics of PCM. This work was initiated in the fourth quarter of year 1 and, in the first quarter of year 2, it is expected that a design will be completed followed by construction of a preliminary protype of PCM during the second and third quarters of year 2 and production of several additional units during year 3. This will be reported in our second Annual Report.

9.3 Software Research and Development

This effort is behind schedule. It was initially decided that Kensal staff (consisting of several software programmers) would produce a Coding Standard and then a Software Specification for the effort involved in producing the software for PCM. After two months effort in the third quarter of year 1, it was recognized that programmers cannot write coding standards and that a full-fledged software engineer was needed. Since it is almost impossible to recruit senior people into a company that is incrementally funded (such as with this grant) we outsourced this work to PlanetTools (Carefree, AZ). Jay Nance (head of PlanetTools) thus started an effort in the third quarter of year 1. Completion is scheduled for the first quarter of year 2. He will produce a software specification and has already written a coding standard. Again, this is a departure from previous plans due to the circumstances described above. Results so far are excellent and it is expected that in year 2 all software will have been completed with preliminary testing taking place on the preliminary prototyped being built in California. In year 3 the amount of effort on software will decrease as only modifications are made and debugging is completed. This will allow us, during year 3, to build and install the additional prototypes. The number of prototypes will depend upon the pricing obtained from our subgrantees.

9.4 Rapid Prototyping

The prototype that ARPA requested be built in a rapid prototyping mode was, as planned, contracted to Boeckeler Instruments, Inc. (Tucson, AZ). The instrument is complete and is being debugged. (All failures have been due to vendor-purchased components and not to any deficiency introduced by Boeckeler Instruments). It is completely described in Section 3 and is performing to its specifications. The only problem has been that, due to malfunctions of the Kodak driver board, the lensless image occasionally is missing a large number of lines. This is currently being corrected as the problem appears to be a "ground loop." Also, one of the "frame grabber" cards from Matrox has developed an input problem where it does not digitize the incoming video. Matrox will replace this card. It is expected that during the first quarter of year 2 the instruments from Boeckeler will be accepted and placed at the hospital of Luke Air Force Base and at the Mayo Clinic. At that time a two-month telemedicine experiment will be conducted during which approximately 50 microscope slides, selected by mutual agreement between Luke and Mayo, will be analyzed by telemedicine. After that, further demonstrations are planned, but the locations are still under discussion. Several organizations have expressed interest in lensless scanning and would like to adopt the Boeckeler instrument to their needs. Other locations (both military and

civilian) have also asked for demonstrations. This list includes professional societies such as the College of American Pathologists.

9.5 Negative Results

As required in Annual Reports under this grant, we herewith present negative results of some significance. There are two such results.

First, Boeckeler Instruments, due to failure of vendor-purchased instruments and hardware, has been unable to deliver their prototypes as rapidly as ARPA initially expected. As noted above, this problem is being rapidly solved. It is not fundamental. The vendors involved in delivering unsatisfactory instrumentation are replacing same at their earliest convenience.

Second, it might be considered a "negative result" that Kensal staff has proved inadequate to (1) produce a software specification for PCM, (2) has been found to have insufficient skills to generate the high-definition television portion of PCM, and (3) requires that the major optomechanical assembly be produced by others. This has slowed our progress but, in the opinion of the PI (Principal Investigator), will, if anything, result in a more superior instrument than one built entirely inhouse. Whereas it had been expected to produce a preliminary of PCM during year 1, this milestone will not be reached until sometime in the third quarter of year 2. This is not a serious negative result in that, in the meantime, we have the rapid prototypes produced by Boeckeler which performed exactly as will the PCM with the exception that they are far more extensive and require far more space on the desktop than would PCM when completed.

In conclusion we feel that the program is going well and that, except for minor delays, is producing excellent results.

9.6 Proposed Staff and Budget Changes

Since research and development is a dynamic process, it is not surprising that a proposal submitted in March of 1994 no longer is applicable exactly to the interval 1 October 1995 to 30 September 1996. Thus this section outlines a rebudgeting of funds for this same interval.

9.6.1 Staffing

Outsourcing has already been discussed above. It has led to the changes described below. Once the project started certain consultants and subcontractors were replaced by more suitable candidates as follows:

Original Subgrantee	Replacement Subgrantee
Neuman DeBell	John Sparks and staff of Optical Systems Corp.
Loral/Lockheed	Loral (Lockheed used only in year 1)
Motorola	Nance, Guerin, Kline (See Sections 7 and 8)
Boeckeler	No change (But used only in year 1)

9.6.2 Budgeting

The amount of the original budget for year 2 is adequate, but funds need to be redeployed to reflect changes in staffing. In particular it is recommended that funds allocated to Loral for a

workstation should now be moved to Optical Systems Corp. in that they will be fabricating the preliminary prototype of PCM. Also the Apple Macintosh 650 that was proposed for use by Loral in 1994 as part of their workstation is now obsolete and will be replaced by one of the far more modern Macintosh 9500/120's that have already been procured by Kensal. Loral will still be used for consulting as they will play a major role in year 3. The original budget and proposed budget, given below, reflect the above changes.

		Year 2 Budget	
		Original (approved 9/94)	Proposed (10/95)
1.	SALARIES (W-2 and 1099) [1]	160,000	160,000
2.	BENEFITS [1]	none	none
3.	CONSULTANTS [2]		
	Neumann	20,000	none
	DeBell	7,000	none
	Nance [2]	none	27,000
4.	EQUIPMENT		
	PCM Assemblies [3]	12,931	12,931
	Optics [3]	21,653	21,653
	Workstations [3]	54,220	54,220
5.	SUPPLIES & MATERIALS [3]	11,281	11,281
6.	TRAVEL		
	PHX-SFO	1,832	1,832
	PHX-SAN	1,408	1,408
7.	ADMINISTRATIVE SUPPORT	none	none
8.	INDIRECT COSTS	62,400	62,400
9.	MISCELLANEOUS [4]		
	Loral	76,300	26,300
	Optical Systems Corp.	none	50,000
10.	TOTAL COST	429,025	429,025

Notes:

[1] Kensal in some cases now supports medical insurance for certain of its employees. When this is done, costs will be taken from salaries.

[2] Hans Neumann and Gary DeBell are not participating in research under this grant since their work on mechanics and optics, respectively, is being done under contract to Optical Systems Corporation. However, due to the increased complexity of our software effort, an outside consultant, J. Nance, will be required to code software for PCM (PC Microscope).

[3] Equipment and supplies needed for the first PCM workstation will be procured by Kensal and furnished as required to Optical Systems Corp.

[4] Optical Systems Corp. will design, fabricate, and test the first prototype PCM workstation. This workstation will be designed to be interfaced to the Loral MDIS system. Procurement of Macintosh computers and color displays from Loral will not be necessary. These will be furnished using existing equipment at Kensal Corp.